through the use of the likelihood information at the time of the maximum likelihood decoding and the transmission rate is allowed to vary, frame by frame, more securely during the transmission (for example, refer to International Publication No. WO97/50219 applied by the present applicant).

In the above-mentioned WO96/26582 and WO97/50219, described is a method where, in order to improve the rate detection performance at the receiving side (that is, to reduce the probability of detecting the rate mistakenly), CRC bits that have been conventionally added to the end of the transmitted data (in this case the position of the CRC bits in the frame depends on the bit length of the transmitted data) are arranged at a fixed position in the frame (for example, at the first position of the frame) and transmitted.

FIGS. 1A and 1B are diagrams showing an example of transmission bit arrangement of the conventional scheme.

In the conventional method where the CRC bits are arranged after transmitted data bits ("conventional postposition"), for example, when a position one bit ahead from the correct rate position is detected, since the codewords at the receiving side goes successively as D1 to D0 and C4 to C1, even if no transmission bit error occurs, the decision result by CRC shows OK (namely, erroneous detection) with a probability of 50 percent. Similarly to this, when a position two bits and three bits ahead from

the correct rate position is detected, the decision result by CRC indicates OK erroneously with a probability of 25 percent and 12.5 percent, respectively.

To solve such a problem that the probability of detecting the rate mistakenly becomes larger as the assumed position approaches the correct rate position, there was devised a method where the CRC bits are arranged at the first position of the frame in the above-mentioned WO96/26582 and WO97/50219. In this method, as shown in FIG. 1B ("preposition" case), since a codeword arrangement at the receiving side is discontinuous as D1, C4 to C1, the above-mentioned problem does not occur and a low probability of detecting the rate mistakenly that is determined by the word length of the CRC code can be obtained constantly, from a detection position adjacent to the correct position to a detection position remote therefrom.

However, in order that the transmitting side arranges the CRC bits always at the first position of the frame, that is, ahead of the transmitted data and transmits, it is essential to store temporarily the whole bits of the transmitted data in memory until calculation of the error-detecting code for the transmitted data is completed. Such buffer memory becomes large in size in proportion to the number of the transmitted data bits of one frame, and when a huge amount of the transmitted data is sent, hardware scale of the memory presents a problem.

On the other hand, in the variable rate data transmission that is assumed in WO96/26582 and WO97/50219, the number of the transmitted data bits in the frame is always a finite value and the case where the number of bits is zero was not described. In actual data transmission, there are cases where the number of the transmitted data bits to be sent becomes zero, for example, as a silent interval in the case of transmission of voice information (namely, an interval when a sender does not talk). It is necessary for the receiving side to perform the rate detection properly including such cases (namely, cases where apparent transmission rate = 0) (this is because there may be a case where, at the receiving side, a decoder of voice codec (CODEC) recognizes that an interval is a silent interval and conducts processing different from that of a non-silent interval, such as generating background noise). A parity bit or parity bits of the conventional error-detecting code (or CRC) is the one that is calculated for a transmitted data sequence of a finite size and transmitted together with the data, and in such cases as mentioned above where the number of the transmitted data bits becomes zero, commonly the error-detecting code is not added. This means that the rate detection method on the basis of the error-detecting code as described in WO96/26582 and WO97/50219 cannot be applied as it is.

Further, in the WO97/50219 described is that by using

the likelihood obtained at the time of conducting the error-correcting decoding (or Viterbi decoding) as rate detection information, a lower probability of detecting the rate mistakenly can be achieved and the rate detection performance can be improved. In the rate detection according to the above-mentioned method, WO97/50219 specifies that the likelihood obtained at each of the assumed final bit positions is compared with a previously-specified value Δ (decision of a threshold) (refer to FIG. 6 in WO97/50219), and in this occasion it is assumed that one kind of Δ value is used in common regardless of the assumed final bit position. However, when this technology is applied in actual radio communication environments, a proper value of Δ for obtaining desired detection performance may differ for each final bit position (i.e. different number of the transmitted data bits in the frame) depending on a distribution tendency of bit transmission errors in the transmission path. For this case, if a single value of Δ is used in common, the rate detection performance varies according to the final bit position; therefore there arises a problem in that average quality of the variable rate data transmission including the rate detection performance changes when a distribution of occurrence probability for transmission rates (final bit positions) varies.

DISCLOSURE OF THE INVENTION

Accordingly, an object of the present invention is, in the variable rate data transmission, to decrease the probability of detecting the rate mistakenly at the receiving side and to eliminate the need for providing buffer for temporarily storing the transmitted data at the transmitting side.

Furthermore, another object of the present invention is, in a broad area of communication environments and variable rate conditions, to make it possible to implement a high-efficiency and high-quality variable rate data transmission.

To solve the above-mentioned first problem, in the present invention, the error-detecting code (for example, the CRC bits) is arranged after the transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other, and the data and code are transmitted.

FIGS. 2A and 2B are diagrams showing examples of the transmission bit arrangements of the conventional scheme and of the scheme according to the present invention. As can be understood from the figures, according to the arrangement of the present invention ("new postposition"), since the codeword arrangement at the receiving side is discontinuous as D1, D0, C0, there does not occur a problem in that the probability of detecting the rate mistakenly increases as the detection position approaches the correct rate position and a low probability of detecting the rate

mistakenly that is determined by the word length of the CRC code can be obtained constantly, from a detection position adjacent to the correct position to a detection position remote therefrom.

Moreover, since the bit arrangement according to the present invention is such that CRC is arranged after the transmitted data, it is not necessary to provide the buffer for temporarily storing the transmitted data while maintaining the rate detection performance high as mentioned above and hardware can be implemented with a small circuit scale.

Furthermore, to solve the above-mentioned second problem, in the present invention, even for the frame whose number of data bits to be transmitted is zero, bits equivalent to the parity bits of the error-detecting code (which has a previously-specified bit pattern) is transmitted (because of absence of data, only this parity-bit equivalent bits are error-correcting coded and transmitted); the receiving side conducts the rate detection including the final bit position when the number of data bits is zero -- regarding the error detection of this case, the calculation of the error-detecting code (re-coding) for the received data is unnecessary and all that is needed is only to compare the received parity-bit equivalent bits with the previously-specified bit pattern. The length of the above-mentioned bit pattern may be the same as that of the parity bits of the

error-detecting code (or CRC) that is given when the number of other data bits is not zero to use the circuit in common. However, these lengths may be different according to need. For the above-mentioned bit pattern, it is necessary to specify previously at least one kind of a pattern, but it may be possible that a plurality of patterns are specified and one of these is used in combination with other purpose (each of various control information is transmitted being mapped with each bit pattern).

Furthermore, to solve the above-mentioned third problem, the present invention makes it possible to conduct the decision-making by setting different values of a set threshold Δ used for threshold decision ($\Delta 1$, $\Delta 2$,... , ΔL,..., ΔN) which are corresponding to respective final bit positions (respective transmission rate), other than a single set threshold. Here, a value of each ΔL may be altered so as to be always an optimal value in accordance with the change of the communication environment. Furthermore, the same value may be used for a part repeatedly if necessary.

In order to accomplish the above-mentioned objects, the invention as claimed in claim 1 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the

transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

transmitting the generated frame data, and

at a receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result.

The invention as claimed in claim 2 is the data transmission method as claimed in claim 1, wherein

at the transmitting side,

if the number of bits of the transmitted data is zero, the step of calculating the error-detecting code

considers a previously-specified bit pattern to be the error-detecting code, and

at the receiving side,

the step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the step of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 3 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data, and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, the step of calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

at the receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein the step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero is also assumed as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern the step

of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 4 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, the step of calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

at a receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit

positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein the step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the step of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 5 is the data transmission method as claimed in any one of claims 1-4, further comprising the steps of:

at the transmitting side,

conducting error-correcting coding of the generated frame data; and

conducting interleaving of the frame data that has undergone the error-correcting coding, and

at the receiving side,

conducting deinterleaving of the received

frame data; and

conducting error-correcting decoding of the frame data that has undergone the deinterleaving.

The invention as claimed in claim 6 is the data transmission method as claimed in claim 5, wherein

at the transmitting side,

the step of generating the frame data generates the frame data containing a tail bit; and

the step of conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

at the receiving side,

the step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence, and

the step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a

predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

The invention as claimed in claim 7 is the data transmission method as claimed in claim 6, wherein at the receiving side, the predetermined range regarding the likelihood difference at the step of deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 8 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data, and at the same time bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone

the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed

transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference at the step of deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 9 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received

frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference at the step of deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 10 is the data transmission method as claimed in any one of claims 6-9, further comprising the step of:

at the transmitting side,

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein the step of generating the frame data generates the frame data containing the calculated transmission rate information, and

at the receiving side,

wherein both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

The invention as claimed in claim 11 is the data transmission method as claimed in claim 10, wherein at the transmitting side, the step of conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

The invention as claimed in claim 12 is the data transmission method as claimed in claim 11, wherein at the transmitting side, the step of conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

The invention as claimed in claim 13 is the data transmission method as claimed in claim 10, wherein at the transmitting side, the step of conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

The invention as claimed in claim 14 is the data transmission method as claimed in any one of claims 10-13, wherein at the receiving side, if the step of deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data, both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data.

The invention as claimed in claim 15 is the data transmission method as claimed in any one of claims 6-14, wherein at the receiving side, if among the assumed

final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, the step of deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

The invention as claimed in claim 16 is the data transmission method as claimed in claim 5, further comprising the step of:

at the transmitting side,

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein the step of generating the frame data generates the frame data containing the calculated transmission rate information and a tail bit, and

the step of conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

at the receiving side,

wherein the step of conducting the error-correcting decoding assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data, frame by frame, for the received frame data, and conducts the error-

correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and

the step of calculating the error-detecting code assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

The invention as claimed in claim 17 is the data transmission method as claimed in claim 16, wherein

at the receiving side, if the step of deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data,

the step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both the step of conducting the error-correcting decoding and the step of calculating the

error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

The invention as claimed in claim 18 is the data transmission method as claimed in claim 17, wherein at the receiving side, the predetermined range regarding the likelihood difference at the step of determining depends on the assumed final bit position of the frame data.

The invention as claimed in claim 19 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

generating frame data containing the

calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code, first, assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the step of deciding does not decide that the assumed position is the final bit position of the frame data,

the step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and the likelihood of the decoded data sequence obtained by terminating the decoding with respect to the

transmitted data sequence,

both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the step of deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 20 is a data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit

positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of the decision result,

wherein both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code, first, assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the step of deciding does not decide that the assumed position is the final bit position of the frame data,

the step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and the likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both the step of conducting the error-correcting decoding and the step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the step of deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 21 is the data transmission method as claimed in any one of claims 17-20, wherein at the receiving side, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and at the same time the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, the step of deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

The invention as claimed in claim 22 is the data transmission method as claimed in any one of claims 16-21, wherein at the transmitting side, the step of conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

The invention as claimed in claim 23 is the data transmission method as claimed in claim 22, wherein at the transmitting side, the step of conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

The invention as claimed in claim 24 is the data transmission method as claimed in any one of claims 16-21, wherein at the transmitting side, the step of conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

The invention as claimed in claim 25 is the data transmission method as claimed in any one of claims 1-24, wherein the error-detecting code is a CRC code.

The invention as claimed in claim 26 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

means for transmitting the generated frame data, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result.

The invention as claimed in claim 27 is the data

transmission system as claimed in claim 26, wherein

in the transmitter,

if the number of bits of the transmitted data is zero, the means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in the receiver,

the means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 28 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code

such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

means for transmitting the generated frame data,

wherein, if the number of bits of the transmitted data is zero, the means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the means for calculating the error-detecting code also assumes a position where the

number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 29 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, the means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 30 is the data transmission system as claimed in any one of claims 26-29,

further comprising:

in the transmitter,

means for conducting error-correcting coding of the generated frame data; and

means for conducting interleaving of the frame data that has undergone the error-correcting coding, and

in the receiver,

means for conducting deinterleaving of the received frame data; and

means for conducting error-correcting decoding of the frame data that has undergone the deinterleaving.

The invention as claimed in claim 31 is the data transmission system as claimed in claim 30, wherein

in the transmitter,

the means for generating the frame data generates the frame data containing a tail bit, and

the means for conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

in the receiver,

the means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final

bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence; and

the means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

The invention as claimed in claim 32 is the data transmission system as claimed in claim 31, wherein in the receiver, the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 33 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data, the calculated error-detecting code, and

a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the

error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference in the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 34 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged

ahead of the corresponding transmitted data;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and

calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 35 is the data transmission system as claimed in any one of claims 31-34, further comprising:

in the transmitter,

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein the means for generating the frame data generates the frame data containing the calculated transmission rate information, and

in the receiver,

wherein both the means for conducting the error-correcting decoding and the means for calculating

the error-detecting code assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

The invention as claimed in claim 36 is the data transmission system as claimed in claim 35, wherein in the transmitter, the means for conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

The invention as claimed in claim 37 is the data transmission system as claimed in claim 36, wherein in the transmitter, the means for conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

The invention as claimed in claim 38 is the data transmission system as claimed in claim 35, wherein in the transmitter, the means for conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

The invention as claimed in claim 39 is the data transmission system as claimed in any one of claims 35-38, wherein in the receiver, if the means for deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information

in the received frame data is the final bit position of the frame data, both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data.

The invention as claimed in claim 40 is the data transmission system as claimed in any one of claims 31-39, wherein in the receiver, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, the means for deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

The invention as claimed in claim 41 is the data transmission system as claimed in claim 30, further comprising:

in the transmitter,

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein the means for generating the frame data generates the frame data containing the calculated

transmission rate information and a tail bit, and

the means for conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

in the receiver,

wherein the means for conducting the error-correcting decoding assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data, frame by frame, for the received frame data, and conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and

the means for calculating the error-detecting code assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

The invention as claimed in claim 42 is the data transmission system as claimed in claim 41, wherein:

in the receiver, if the means for deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data,

the means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum

likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

The invention as claimed in claim 43 is the data transmission system as claimed in claim 42, wherein in the receiver, the predetermined range regarding the likelihood difference at the means for determining depends on the assumed final bit position of the frame data.

The invention as claimed in claim 44 is a data

transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

means for generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the

frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the means for conducting the error-correcting decoding and the means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the means for deciding does not decide that the assumed position is the final bit position of the frame data,

the means for conducting the error-

correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequences,

both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 45 is a data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

means for generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a transmitter,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has

undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the means for deciding does not decide that the assumed position is the final bit position of the frame data,

the means for conducting error-correcting decoding assumes the final bit position of the

frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the assumed final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data; and

the means for determining determines that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 46 is the data transmission system as claimed in any one of claims 42-45, wherein in the receiver, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, the means for deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

The invention as claimed in claim 47 is the data transmission system as claimed in any one of claims 41-46, wherein in the transmitter, the means for conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

The invention as claimed in claim 48 is the data transmission system as claimed in claim 47, wherein in the transmitter, the means for conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

The invention as claimed in claim 49 is the data transmission system as claimed in any one of claims 41-46, wherein in the transmitter, the means for conducting the

error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

The invention as claimed in claim 50 is the data transmission system as claimed in any one of claims 26-49, wherein the error-detecting code is a CRC code.

The invention as claimed in claim 51 is a transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

means for transmitting the generated frame data.

The invention as claimed in claim 52 is a transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the

corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, the means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code.

The invention as claimed in claim 53 is a transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, the means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code.

The invention as claimed in claim 54 is a receiver for receiving frame data containing variable length transmitted data, and an error-detecting code calculated, frame by frame, for the transmitted data in each frame of a fixed time length such that the error-detecting code is

arranged after the corresponding transmitted data, and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result.

The invention as claimed in claim 55 is a receiver for receiving frame data containing variable length transmitted data and an error-detecting code calculated, frame by frame, for the transmitted data in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, and if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-

detecting code, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with the previously-specified bit pattern, the means for determining determines that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 56 is a receiver for receiving frame data containing variable length

transmitted data and an error-detecting code calculated, frame by frame, for the transmit data in each frame of a fixed time length such that the error-detecting code is arranged ahead of the corresponding transmitted data, and if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data

agrees with the previously-specified bit pattern, the means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

The invention as claimed in claim 57 is a receiver for receiving frame data containing variable length transmitted data, an error-detecting code calculated, frame by frame, for the transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, if the number of bits of the transmitted data is zero, the previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data

sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 58 is a receiver for receiving frame data containing variable length transmitted data, an error-detecting code calculated, frame by frame, for the transmitted data, and a tail bit in each frame of a fixed time length such that the

error-detecting code is arranged ahead of the corresponding transmitted data, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit

positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein the predetermined range regarding the likelihood difference at the means for deciding depends on the assumed final bit position of the frame data.

The invention as claimed in claim 59 is a receiver for receiving frame data containing variable length transmitted data, transmission rate information indicating the number of bits of the transmitted data calculated, frame by frame, for the transmitted data, an error-detecting code calculated, frame by frame, for the transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and at the same time the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the means

for deciding does not decide that the assumed position is the final bit position of the frame data,

the means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the means for determining depends on the assumed final bit position of the frame data.

The invention as claimed in claim 60 is a receiver for receiving frame data containing variable length transmitted data, transmission rate information indicating the number of bits of the transmitted data calculated, frame by frame, for the transmitted data, an error-detecting code calculated, frame by frame, for the transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged ahead of the corresponding transmitted data, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position

of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and at the same time the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of the decision result,

wherein both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if the means for deciding does not decide that the assumed position is the final bit position of the frame data,

the means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at the assumed final bit position, calculates the likelihood difference between the maximum of

likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both the means for conducting the error-correcting decoding and the means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

the means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at the means for determining depends on the assumed final bit position of the frame data.

According to the foregoing configuration, in the variable rate data transmission, the need for providing buffer for temporarily storing the transmitted data at the transmitting side can be eliminated while holding down the probability of detecting the rate mistakenly at the receiving side.

Moreover, in the broad area of communication environments and variable rate conditions, a high-efficiency and high-quality variable rate data transmission is made possible.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are diagrams showing examples of transmission bit arrangements of the conventional scheme;

FIGS. 2A and 2B are diagrams showing examples of the transmission bit arrangement of the conventional scheme and of the transmission bit arrangement according to the present invention;

FIGS. 3A and 3B are block diagrams showing examples of configurations of a transmitter and a receiver in a first embodiment according to the present invention;

FIGS. 4A and 4B are diagrams showing examples of frame configurations of the transmitted data in the first embodiment according to the present invention;

FIG. 5 is a diagram illustrating a processing example of an interleaver in the first embodiment according to the present invention;

FIG. 6 is a diagram showing an example of a frame configuration of the transmitted data in the first embodiment according to the present invention;

FIG. 7 is a diagram showing an example of a decoded data sequence at the time of the maximum likelihood decoding in the first embodiment according to the present

invention;

FIG. 8 is a flowchart of a processing example of rate decision in the first embodiment according to the present invention;

FIG. 9 is a diagram showing relationship between FIGS. 9A and 9B;

FIGS. 9A and 9B are flowcharts of another processing example of rate decision in the first embodiment according to the present invention;

FIGS. 10A and 10B are block diagrams showing examples of the configurations of the transmitter and the receiver in a second embodiment according to the present invention;

FIGS. 11A and 11B are diagrams showing examples of the frame configurations of the transmitted data in the second embodiment according to the present invention;

FIG. 12 is a flowchart of a processing example of rate decision in the second embodiment according to the present invention;

FIG. 13 is a diagram showing the frame and the final bit positions therein;

FIGS. 14A and 14B are diagrams showing examples of the frame configurations of the transmitted data in the case of the "postposition and same order";

FIGS. 15A and 15B are diagrams showing examples of the frame configuration of the transmitted data in the case of the "preposition"; and

FIGS. 16A and 16B are diagrams showing examples where

frame memory and error-detecting code memory are added to the configuration of the "preposition" case.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereafter, preferred embodiments to implement the present invention will be described in detail with reference to the drawings.

(FIRST EMBODIMENT)

FIGS. 3A and 3B show examples of block constructs of a transmitter and a receiver in a first embodiment of the present invention.

In FIGS. 3A and 3B, a transmitted data sequence applied to a terminal 1 is sent both to an error-detecting coder 4 and to a multiplexer 6. The error-detecting coder 4 calculates the error-detecting code (in this embodiment, CRC parity bits (in short, CRC bits)) for one frame of the transmitted data. In this embodiment, the word length of the CRC bits is a fixed length.

Next, the multiplexer 6 arranges the error-detecting code (the CRC bits) calculated by the error-detecting coder 4 after the transmitted data. Here, the bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other. Concretely, in this embodiment, the error-detecting coder 4 outputs the error-detecting code bits in a reverse order to the normal case.

By the way, in this embodiment, to conduct the

error-correcting coding with a convolutional code, the multiplexer 6 further adds tail bit(s) that will be necessary for the error-correcting decoding to the transmitted data and the error-detecting code, and outputs these sequentially, frame by frame.

FIGS. 4A and 4B show examples of the data sequence outputted from the multiplexer 6. Here, FIG. 4A shows the case where the transmission rate of the transmitted data is the maximum and FIG. 4B shows the case where the transmission rate of the transmitted data is below the maximum rate, respectively. When transmission is conducted at a transmission rate below the maximum rate, a blank time (time without data) emerges in the frame.

The data sequence outputted from the multiplexer 6 undergoes convolutional coding in an error-correcting coder 8 and sent to an interleaver 10 to be interleaved.

FIG. 5 shows an example of the interleaving by the interleaver 10. The data sequence of one frame is outputted in a direction different from a direction in which the data is inputted, that is, the transmitted data inputted in a line direction is outputted in a column direction. Incidentally, as for another example of the interleaving, the interleaving processing described in Japanese Patent Application No. 11-129056 applied by the present applicant can be enumerated. The data sequence outputted from the interleaver 10 is written into s frame memory 12.

FIG. 6 shows an example of the frame configuration of the data sequence obtained from the frame memory 12. The data interval corresponding to the column of the interleaver 10 is called a slot, and here it is assumed that one slot is composed of N bits and one frame is composed of M slots. The number of bits of one frame becomes N x M bits.

The output data sequence of the frame memory 12 is modulated by a radio circuit 14 and transmitted through an antenna 16. Here, for modulation schemes, for example, a spread spectrum modulation scheme, a QPSK modulation scheme, etc. are used. In addition, it is specified that no modulation is conducted at a data position corresponding to blank data in the slot. According to the foregoing, the data consisting of variable number of bits is made to be transmitted in a constant frame time.

Next, in the receiver, the received signals fed from an antenna 20 is demodulated by a radio circuit 22 and then inputted into a deinterleaver 24 sequentially. The deinterleaver 24 has a memory in it and conducts the interleaving in such a procedure that inputting into and outputting from the interleaver 10 at the transmitting side are reversed, that is, writing the data into the memory for each column (each slot) and reading the data for each line. Through such operations as these, an original data sequence of one frame is reproduced and the coded transmitted data sequence and the error-detecting code are

revealed. The interleaving and the deinterleaving mentioned just above are intended to enhance an error correction effect even further by preventing burst errors as detected in consecutive data bits.

The deinterleaved data sequence is sent to an error-correcting decoder 26 and undergoes the error-correcting decoding by the maximum likelihood decoding method, and the decoded data sequence is separated into the error-detecting code and the data sequence by a demultiplexer 28, and the error-detecting code is inputted into a comparator 34.

On the other hand, the data sequence is outputted from a terminal 2 as received data and at the same time inputted into an error-detecting coder 30. At the error-detecting coder 30, the inputted data sequence undergoes the same error-detecting coding as that of the transmitter again. The error-detecting code obtained by re-coding is compared with the error-detecting code so separated, code-bit by code-bit, by the comparator 34, and if all the code bits are found to agree with each other, a coincidence signal is outputted. In addition, since the error-correcting code bits in the received frame are in a reverse order to the normal case, the error-detecting coder 30 in this embodiment outputs the error-correcting code bits in a reverse order to the normal case.

Here, the error-correcting decoding and the calculation of the error-detecting code are conducted,

frame by frame, by successively assuming the final bit position of transmittable frame data. At this occasion, the error-correcting decoder 26 sends likelihood information for a decoding result up to each of the assumed final bit positions to a rate decision circuit 36, and the rate decision circuit 36 decides the final bit position, namely, the transmission rate of the frame on the basis of this likelihood information and the coincidence signal of the error-detecting codes.

FIG. 7 shows an example of the decoded data sequence at the time of the maximum likelihood decoding, and FIG. 8 shows an example of the processing of rate decision (algorithm). Here, for the maximum likelihood decoding, Viterbi decoding is assumed.

First, after Viterbi decoding starts, regarding a plurality of decoded data sequences each of which still remains in each state (in the example of FIG. 7, K pieces of the decoded data sequences that reach the states 1 to K) at the assumed final bit position (in the example of FIGS. 7 and 8, the position #L), the likelihoods with respect to the transmitted data sequence of those are obtained, respectively, and a difference between the maximum value of these likelihood and a likelihood with respect to the transmitted data sequence of the decoded data sequence (in the example of FIG. 7, the data sequence that reaches the state 0) obtained by terminating the decoding process is obtained (steps S1 to S4).

If this likelihood difference is within a certain range (in the example of FIG. 8, within Δ), the selected decoded data sequence is outputted by traceback and the error-detecting coding (CRC coding) is conducted (steps S5 and S6).

Since in this embodiment the word length of the CRC code is a fixed length and a frame configuration that the transmitted data is arranged just ahead of the CRC code is adopted, (assumed) transmitted data (part) and the (assumed) error-detecting code (part) for the assumed final bit position can be obtained. That is, by assuming the final bit position, the transmitted data (part) and the error-detecting code (part) are concomitantly assumed. Then, the obtained (assumed) transmitted data undergoes the error-detecting (re-)coding (CRC coding).

If this re-coded CRC agrees with the received CRC ((assumed) error-detecting code), the decoding is ended and the transmitted data is acquired (restored) by deciding that the assumed final bit position is the final bit position of the transmitted frame data. Since the bit arrangements of the transmitted data in the frame and of the error-detecting code are in a reverse order to each other, the probability that a comparison result of CRCs indicates coincidence erroneously is extremely small.

If the likelihood difference exceeds Δ or the comparison result of CRCs indicates no coincidence, a next position is assumed and Viterbi decoding is continued. In

addition, if there are detected a plurality of positions where the likelihood difference is within Δ and the comparison result of the error-detecting codes indicates coincidence when Viterbi decoding and the calculation of the error-detecting code are conducted for the assumed final bit positions, a decision that a position where the likelihood difference becomes the minimum is the final bit position of the transmitted frame data may be made. This will be described later.

In the example of FIG. 7, if no error occurs on the way of transmission, it is reasonable to think as follows: a sequence that reaches the state 0 at the second position (L=2) has the maximum likelihood (likelihood difference = 0) and the comparison result of the error-detecting codes for this decoded sequence indicates coincidence.

On the other hand, if an error or errors occurs on the may of transmission, a sequence that reaches the state 0 does not necessarily have the maximum likelihood. Accordingly, by setting Δ to an appropriate value, the same effect of reduction in the rate-decision error rate as that in the case of no transmission error can be obtained also for the decoded sequence such that occurred errors have been corrected. In a region where the value of Δ is not more than a certain value, by setting Δ to a smaller value, an average rate-decision error rate can be lowered further; an average frame error rate (the probability that the comparison result of CRCs indicates no coincidence + the

rate-decision error rate) becomes larger.

Therefore, for example, for data that requires an extremely low rate-decision error rate, such as control data, it is better to make Δ smaller at the cost of the frame error rate to some degree.

Alternatively, considering tendency of the errors that occur during the transmission with respect to Δ, the difference between the maximum and the minimum of the likelihoods obtained at respective assumed final bit positions is regarded as a factor and a constant value multiplied by this factor may be set as Δ.

When data transmission is conducted using the transmitter and the receiver of such configurations as in the foregoing, even if the receiving side varies the number of bits in the frame (namely, apparent transmission rate) without sending any information indicating the number of transmission bits in the frame from the receiving side, the receiving side can receive the data.

In addition, this scheme makes it possible both, at the receiving side, to lower the probability of detecting the rate mistakenly during transmitting the variable rate data, and at the transmitting side, to eliminate the need for providing buffer for temporarily storing the transmitted data .

Furthermore, by adopting the rate decision method that uses jointly the likelihood information during Viterbi decoding, it is possible to lower the possibility

of outputting the transmitted data of an erroneous length in the frame on the basis of the erroneous decision result of the rate, and thus a highly-reliabile variable rate data transmission can be conducted.

As described above, if there are detected a plurality of positions where the likelihood difference is within Δ and the comparison result of the error-detecting codes indicates coincidence when Viterbi decoding and the calculation of the error-detecting code are conducted for the assumed final bit positions, a decision that a position where the likelihood difference becomes the minimum is the final bit position of the transmitted frame data may be made.

FIGS. 9A and 9B show another example of the processing of rate decision (algorithm). In the example of FIGS. 9A and 9B, -- representing the assumed bit position as L -- an assumed first position (L=1, or alternatively as described in a third embodiment, L=0 is allowable) through an assumed final position (at step S31, whether or not the assumed final position has been checked is judged) are thoroughly checked and then a decision that a position where the likelihood difference is the minimum is the final bit position is made. In this occasion, a variable S_{min} for storing the minimum likelihood difference and a variable L' for storing its position are used.

However, it is conceivable that there is a case where the likelihood difference is within Δ and not a single

position where the comparison result of the error-detecting codes indicates coincidence is detected. Since in that case, even at the stage of step S33, L' satisfies L'=-1 (a value that was set at step S21), it may be allowed that the case is assumed as, for example, an error. In addition, if the value of Δ is set to infinity, a situation that not a single position where the likelihood difference is within Δ is detected can be avoided.

In this embodiment, the error-correcting coding is conducted with a convolutional code, but the error-correcting coding may be done by means of other method, for example, one with a turbo code. Furthermore, as the above-mentioned WO97/50219, the frame data may be divided into a plurality of blocks and each block may undergo the error-correcting coding with a block code.

Moreover, in this embodiment, the frame data undergoes the error-correcting coding and the interleaving as well as the deinterleaving and the error-correcting decoding. However, without these operations, it is possible that the probability of detecting the rate mistakenly in the variable rate data transmission is suppressed to low and that the need for providing buffer for temporarily storing the transmitted data is eliminated. In that case, all that is needed is that among the assumed final bit positions of the assumed frame data, a position where the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed

transmitted data is simply decided to be the final bit position of the frame data, without using the likelihood information.

(SECOND EMBODIMENT)

FIGS. 10A and 10B show examples of the block constructs of a transmitter and a receiver in a second embodiment according to the present invention.

In the configuration of FIGS. 10A and 10B, transmission of information indicating the rate of the transmitted data is added to the configuration of FIGS. 3A and 3B, and the receiving side uses this rate information additionally to make the rate decision. In FIGS. 10A and 10B, all the parts common to those of the configurations of FIGS. 3A and 3B are denoted by the same numerals. Description of operations will be given below, focusing on parts different from those of FIGS. 3A and 3B.

First, information indicating the rate of the transmitted data (transmission rate information) that is applied to the terminal 5 is sent to a rate information memory 40. Here, the contents of the rate information memory 40 are information indicating the rate information of the transmitted data, namely, the number of bits. A multiplexer 6′ outputs the following information successively, frame by frame: information indicating the rate of the transmitted data being read from the rate information memory 40; the transmitted data sent from the terminal 1; the error-detecting code calculated by the

error-detecting coder 4; and the tail bits. Also here, the error-detecting code is arranged after the transmitted data and at the same time the bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other. In addition, in this embodiment, the transmission rate information is arranged at the first position of the frame.

FIGS. 11A and 11B show examples of the data sequences outputted from the multiplexer 6'.

In this embodiment, the error-correcting coder 8 conducts the error-correcting coding with a block code for the transmission rate information (as examples of concrete error-correcting codes, one may enumerate a double orthogonal code, Reed-Muller code, BCH code, etc. or alternatively error-correcting coding other than the error-correcting coding with a block code may be used), and does the error-correcting coding with a convolutional code for the transmitted data, the error-detecting code, and the tail bits. Furthermore, the interleaver 10 conducts the interleaving of these data that have undergone the error-correcting coding, either independently for each data or collectively. In addition, in the error-correcting coder 8, all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bits may undergo collectively the error-correcting coding with a convolutional code.

On the other hand, in the receiver, if the

transmission rate information undergoes the error-correcting coding with a block code or the like independently from the transmitted data or the like, the transmission rate information part undergoes the error-correcting decoding properly in an error-correcting decoder 26' and subsequently the decoding result is retained in a rate information memory 42. On the contrary, if the transmission rate information, the transmitted data, etc. undergo convolutional-coding collectively, in the error-correcting decoder 26' the decoding result of the rate information bits part arranged at the first position of the frame is temporarily obtained by interrupting sequential Viterbi decoding that has been started from the first position of the frame, and this decoding result is retained in the rate information memory 42.

FIG. 12 shows the rate decision processing (algorithm) in the receiver of this embodiment. The error-correcting decoder 26' assumes a position indicated by the contents of the rate information memory 42 as the final bit position, continues to conduct Viterbi decoding of the frame data up to that position, outputs the decoded data sequence obtained by terminating the decoding process through traceback, and conducts the error-detecting coding (CRC coding) (steps S11 to S15).

If the re-coded CRC agrees with the received CRC the decoding process is completed (step S16), a decision that the position indicated by the contents of the rate

information memory is the final bit position of the transmitted frame data is made and the transmitted data is acquired (restored). Since the bit arrangements of the transmitted data in the frame and of the error-detecting code are set in a reverse order to each other, the probability that the comparison result of CRCs indicates coincidence erroneously is extremely small.

In this embodiment, if the comparison result of CRCs indicates no coincidence, the final position of the transmittable frame data other than the final bit position indicated by the contents of the rate information memory is assumed successively, the error-correcting decoding and the calculation of the error-detecting code are conducted, and the rate decision is made using the likelihood information during Viterbi decoding and the comparison result of the error-detecting codes (the same processing as step S17 and steps S1 to S8 of FIG. 8).

Also, between steps S13 and S14, similarly to the first embodiment, the following steps may be added: determining the maximum likelihood (step S3); finding the likelihood difference (step S4); and judging whether or not the likelihood difference is within a certain range (step S5). Concrete processes may be as follows: if the likelihood difference is within a certain range, the flow is made to proceed to step S14; if the likelihood difference is not within a certain range, the flow is made to proceed to step S17. In the case where such processing (steps S3

to S5) is conducted, although the number of processes increase as compared to when such processing is not done, the rate-decision error rate can be improved further. In addition, Δ used at step S5 between step S13 and step S14 and Δ used at step S5 while being in step S17 may be the same value or may be different values.

Also in the case where the transmitter and the receiver of the foregoing configurations are used to conduct the data transmission, it is possible that the probability of detecting the rate mistakenly at the receiving side during transmitting variable rate data is suppressed to low and that the need for providing buffer for temporarily storing the transmitted data at the transmitting side is eliminated.

Moreover, if there is no transmission error, the rate information is surely detected by the receiver; on the other hand, supposing that the rate information is transmitted erroneously, the rate decision is made possible through the use of likelihood information during Viterbi decoding and the comparison result of the error-detecting codes, so that the final frame error rate is improved and a low rate-decision error rate is achieved. By this means, the highly-reliabile variable rate data transmission can be performed.

In addition, since the reliability of Viterbi decoding result of the rate information bit part can be made larger as the input signal stored in the decoder,

namely, the length of the subsequent coded data sequence becomes longer in the foregoing description, it is preferable that the data sequences of a fixed length other than the transmitted data, such as the error-detecting code, are arranged just after the rate information bits successively as much as possible.

Alternatively, it may be also possible that in the transmitter the tail bits are inserted after the rate information bits, and in the receiver the decoding operation is temporarily completed at this tail bits, and after the received rate information is obtained, the decoding operation is re-started to decode the frame data up to the final bit.

(THIRD EMBODIMENT)

In the first embodiment and the second embodiment, it is possible that, considering a case where the number of bits of the transmitted data becomes zero, if the number of bits of the transmitted data is zero at the transmitting side, the frame data is generated by considering the previously-specified bit pattern to be the error-detecting code. It is possible that at the receiving side, a position where the number of bits of the transmitted data becomes zero is also assumed as the final bit position of the frame data (that is, in FIG. 13, a position where L=0 is also assumed as the final bit position of the frame data), and if the error-detecting code in the case of the the assumption agrees with the above-mentioned previously-

specified bit pattern, a decision that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data is made.

In actual data transmissions, there is a case where the number of bits of the transmitted data to be sent becomes zero, for example, as a silent interval (namely, an interval when a sender does not speak) in the case of transmission of voice information, and it is preferable that the receiving side conducts the rate detection correctly for various cases including a case like this (that is, a case where apparent transmission rate = 0) (this is because at the receiving side a decoder of voice codec (CODEC) may recognize such an interval as a silent interval and conduct processing different from that of non-silent intervals, such as generation of a background noise).

For the previously-specified bit pattern, for example, bits equivalent to the parity bits of the error-detecting code (because of absence of the data, bits corresponding to an initial state of the error-detecting coder; for example, bits all consisting of zeros) may be used. If the number of bits of the transmitted data is zero, the transmitting side transmits the bits equivalent to the parity bits of the error-detecting code (because of absence of the data, only these bits equivalent to the parity bits are error-correcting coded and transmitted). At the receiving side, the rate detection is conducted for candidate final bit positions including the final bit

position when the number of data bits is equal to zero (the error detection at this occasion does not necessitate calculating the error-detecting code for the received data -- re-encoding -- , and all that is needed is only to compare the received parity-bit equivalent bits with the previously-specified bit pattern). Incidentally, if the bits equivalent to the parity bits of the error-detecting code is used as the previously-specified bit pattern, the need for additionally providing a circuit for generating the previously-specified bit pattern can be eliminated.

Although the circuit can be used in common by equalizing the length of the bit pattern with that of the parity bits of the error-detecting code (or CRC) that is given when the number of the other data bits is not zero, the length may be different as the need arises.

For the bit pattern, it is necessary to specify previously at least one kind of a pattern, but it may be possible that a plurality of patterns are specified and one of these is used in combination with other purpose (each of various control information is transmitted being mapped with each bit pattern).

(FOURTH EMBODIMENT)

In the first embodiment through the third embodiment, it is possible that in judging (at the receiving side) whether or not the likelihood difference is within the predetermined range (step S5 in FIG. 8), the predetermined range (the value of Δ in FIG. 8) is varied (is made

different) according to the assumed final bit position of the frame data.

When the present invention is applied in actual radio communicaiton environments, a proper value of Δ to obtain the desired detection performance may differ for each of the final bit positions (that is, different number of bits of the transmitted data in the frame) depending on the tendency of the transmission bit errors in the transmission path. In such cases, if a single value of Δ is used in common, the rate detection performance differs according to the final bit position. Consequently, there arises a problem in that when a percentage of transmission frequencies of the transmission rates (final bit positions) vary, the average quality of the variable rate data transmission including the rate detection performance changes.

Then, it is conceivable that the value of Δ for the decision of the threshold value is set to not a single value but several different values ($\Delta 1$, $\Delta 2$,... ,ΔL,... , ΔN) for respective final bit positions (respective transmission rates) and thereby the decision of the rate is made possible. Here, a value of each ΔL may be varied during the transmission so as to be always an optimum value in response to the change in the transmission environment. Furthermore, the same value may be used in part repeatedly.

(OTHERS)

The techniques described in the third and fourth

embodiments may be applied both to the case of "postposition and same order" (that is, a case where the error-detecting code is arranged after the transmitted data and the bit arrangements of the transmitted data and of the error-detecting code are set in the same order) and to the case of "preposition" (that is, a case where the error-detecting code is arranged ahead of the transmitted data and the bit arrangements may be in the same order or in a reverse order).

FIGS. 14A and 14B show examples of the frame configurations of the transmitted data in the case of "postposition and same order," and FIGS. 15A and 15B show examples of the frame configurations of the transmitted data in the case of "preposition." Configuration examples of the transmitter and the receiver used in the case of "postposition and same order" and in the case of "preposition," a processing example, and the like are the same as those of FIGS. 3A and 3B through FIG. 12. In addition, in the case of "preposition," as shown in FIGS. 16A and 16B, it is conceivable that, for example a frame memory 40 is provided between the terminal 1 and the multiplexer 6 and thereby the transmitted data is temporarily stored, and in the mean time the error-detecting code is calculated by the error-detecting coder 4. Moreover, it is conceivable that, for example, an error-detecting code memory 42 is provided between the demultiplexer 28 and the comparator 34 and thereby the

assumed error-detecting code is temporarily stored, and in the meantime the error-detecting code of the assumed transmitted data is calculated by the error-detecting coder 30.

As explained in the foregoing, according to the present invention, in the variable rate data transmission, the probability of detecting the rate mistakenly at the receiving side can be suppressed to low and the need for providing buffer for temporarily storing the transmitted data at the transmitting side can be eliminated.

Moreover, in the broad area of communication environments and variable rate conditions, highly-efficient variable rate data transmission of high-quality is made possible.

WHAT IS CLAIMED IS:

1. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

transmitting the generated frame data, and

at a receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result.

2. The data transmission method as claimed in claim 1, wherein

at the transmitting side,

if the number of bits of the transmitted data is zero, said step of calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

at the receiving side,

said step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said step of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

3. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data, and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, said step of calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

at the receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein said step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero is also assumed as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern said step of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

4. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, said step of calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

at a receiving side,

receiving the frame data;

assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein said step of calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said step of deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

5. The data transmission method as claimed in any one

of claims 1-4, further comprising the steps of:

at the transmitting side,

conducting error-correcting coding of the generated frame data; and

conducting interleaving of the frame data that has undergone the error-correcting coding, and

at the receiving side,

conducting deinterleaving of the received frame data; and

conducting error-correcting decoding of the frame data that has undergone the deinterleaving.

6. The data transmission method as claimed in claim 5, wherein

at the transmitting side,

said step of generating the frame data generates the frame data containing a tail bit; and

said step of conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

at the receiving side,

said step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final

bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence, and

said step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

7. The data transmission method as claimed in claim 6, wherein at the receiving side, the predetermined range regarding the likelihood difference at said step of deciding depends on the assumed final bit position of the frame data.

8. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the

transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data, and at the same time bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at the assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

assuming the transmitted data and the

error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference at said step of deciding depends on the assumed final bit position of the frame data.

9. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged

ahead of the corresponding transmitted data;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed

transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference at said step of deciding depends on the assumed final bit position of the frame data.

10. The data transmission method as claimed in any one of claims 6-9, further comprising the step of:

at the transmitting side,

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein said step of generating the frame data generates the frame data containing the calculated transmission rate information, and

at the receiving side,

wherein both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code assume the final bit position of the

frame data on the basis of the transmission rate information in the received frame data.

11. The data transmission method as claimed in claim 10, wherein at the transmitting side, said step of conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

12. The data transmission method as claimed in claim 11, wherein at the transmitting side, said step of conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

13. The data transmission method as claimed in claim 10, wherein at the transmitting side, said step of conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

14. The data transmission method as claimed in any one of claims 10-13, wherein at the receiving side, if said step of deciding does not decide that the final bit position

of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data, both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data.

15. The data transmission method as claimed in any one of claims 6-14, wherein at the receiving side, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, said step of deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

16. The data transmission method as claimed in claim 5, further comprising the step of:

at the transmitting side,

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein said step of generating the frame data

generates the frame data containing the calculated transmission rate information and a tail bit, and

said step of conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

at the receiving side,

wherein said step of conducting the error-correcting decoding assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data, frame by frame, for the received frame data, and conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and

said step of calculating the error-detecting code assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

17. The data transmission method as claimed in claim 16, wherein

at the receiving side, if said step of deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data,

said step of conducting the error-correcting decoding assumes the final bit position of the frame data,

frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

18. The data transmission method as claimed in claim 17, wherein at the receiving side, the predetermined range regarding the likelihood difference at said step of

determining depends on the assumed final bit position of the frame data.

19. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code, first, assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said step

of deciding does not decide that the assumed position is the final bit position of the frame data,

said step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and the likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at said step of deciding depends on the assumed final bit position of the frame data.

20. A data transmission method that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising the steps of:

at a transmitting side,

calculating an error-detecting code of the transmitted data, frame by frame;

calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

conducting error-correcting coding of the generated frame data with a convolutional code;

conducting interleaving of the frame data that has undergone the error-correcting coding; and

transmitting the frame data that has undergone the interleaving, and

at a receiving side,

receiving the frame data;

conducting deinterleaving of the received

frame data;

assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position;

assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

acquiring the transmitted data on the basis of said decision result,

wherein both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code, first, assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said step of deciding does not decide that the assumed position is

the final bit position of the frame data,

said step of conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and the likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said step of conducting the error-correcting decoding and said step of calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said step of deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the

likelihood difference at said step of deciding depends on the assumed final bit position of the frame data.

21. The data transmission method as claimed in any one of claims 17-20, wherein at the receiving side, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and at the same time the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, said step of deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

22. The data transmission method as claimed in any one of claims 16-21, wherein at the transmitting side, said step of conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

23. The data transmission method as claimed in claim 22, wherein at the transmitting side, said step of conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

24. The data transmission method as claimed in any one of claims 16-21, wherein at the transmitting side, said step of conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

25. The data transmission method as claimed in any one of claims 1-24, wherein said error-detecting code is a CRC code.

26. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

means for transmitting the generated frame data, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result.

27. The data transmission system as claimed in claim 26, wherein

in the transmitter,

if the number of bits of the transmitted data is zero, said means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in the receiver,

said means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position

of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

28. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

means for transmitting the generated frame data,

wherein, if the number of bits of the transmitted data is zero, said means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein said means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

29. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, said means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code, and

in a receiver,

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed

transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein said means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

30. The data transmission system as claimed in any one of claims 26-29, further comprising:

in the transmitter,

means for conducting error-correcting coding of the generated frame data; and

means for conducting interleaving of the frame data that has undergone the error-correcting coding, and

in the receiver,

means for conducting deinterleaving of the received frame data; and

means for conducting error-correcting

decoding of the frame data that has undergone the deinterleaving.

31. The data transmission system as claimed in claim 30, wherein

in the transmitter,

said means for generating the frame data generates the frame data containing a tail bit, and

said means for conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

in the receiver,

said means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence; and

said means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a

predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

32. The data transmission system as claimed in claim 31, wherein in the receiver, the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

33. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has

undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to the assumed final bit position, and at said assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the

error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference in said means for deciding depends on the assumed final bit position of the frame data.

34. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

35. The data transmission system as claimed in any one of claims 31-34, further comprising:

in the transmitter,

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein said means for generating the frame data generates the frame data containing the calculated transmission rate information, and

in the receiver,

wherein both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

36. The data transmission system as claimed in claim 35, wherein in the transmitter, said means for conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the

transmitted data, the error-detecting code, and the tail bit.

37. The data transmission system as claimed in claim 36, wherein in the transmitter, said means for conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

38. The data transmission system as claimed in claim 35, wherein in the transmitter, said means for conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional code.

39. The data transmission system as claimed in any one of claims 35-38, wherein in the receiver, if said means for deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data, both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame

data.

40. The data transmission system as claimed in any one of claims 31-39, wherein in the receiver, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, said means for deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

41. The data transmission system as claimed in claim 30, further comprising:

in the transmitter,

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame,

wherein said means for generating the frame data generates the frame data containing the calculated transmission rate information and a tail bit, and

said means for conducting the error-correcting coding conducts the error-correcting coding with a convolutional code, and

in the receiver,

wherein said means for conducting the

error-correcting decoding assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data, frame by frame, for the received frame data, and conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and

said means for calculating the error-detecting code assumes the final bit position of the frame data on the basis of the transmission rate information in the received frame data.

42. The data transmission system as claimed in claim 41, wherein:

in the receiver, if said means for deciding does not decide that the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data is the final bit position of the frame data,

said means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data

sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data.

43. The data transmission system as claimed in claim 42, wherein in the receiver, the predetermined range regarding the likelihood difference at said means for determining depends on the assumed final bit position of the frame data.

44. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code

of the transmitted data, frame by frame;

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

means for generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a receiver,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position;

means for assuming the transmitted data and the

error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein said means for conducting the error-correcting decoding and said means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said means for deciding does not decide that the assumed position is the final bit position of the frame data,

said means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position,

calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequences,

both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

45. A data transmission system that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

in a transmitter,

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for calculating transmission rate information indicating the number of bits of the transmitted data, frame by frame;

means for generating frame data containing the calculated transmission rate information, the transmitted data, the calculated error-detecting code, and a tail bit such that the error-detecting code is arranged ahead of the corresponding transmitted data;

means for conducting error-correcting coding of the generated frame data with a convolutional code;

means for conducting interleaving of the frame data that has undergone the error-correcting coding; and

means for transmitting the frame data that has undergone the interleaving, and

in a transmitter,

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position

of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said means for deciding does not decide that the assumed position is the final bit position of the frame data,

said means for conducting error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates the likelihood difference between the maximum

of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the assumed final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data; and

said means for determining determines that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

46. The data transmission system as claimed in any one of claims 42-45, wherein in the receiver, if among the assumed final bit positions of the frame data exist a plurality of positions where the obtained likelihood

difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data, said means for deciding decides that a position where the obtained likelihood difference becomes the minimum is the final bit position of the frame data.

47. The data transmission system as claimed in any one of claims 41-46, wherein in the transmitter, said means for conducting the error-correcting coding conducts, for the transmission rate information, independent error-correcting coding that is separate from the error-correcting coding for the transmitted data, the error-detecting code, and the tail bit.

48. The data transmission system as claimed in claim 47, wherein in the transmitter, said means for conducting the error-correcting coding conducts the error-correcting coding of the transmission rate information by using a block code.

49. The data transmission system as claimed in any one of claims 41-46, wherein in the transmitter, said means for conducting the error-correcting coding conducts the error-correcting coding of all of the transmission rate information, the transmitted data, the error-detecting code, and the tail bit collectively with a convolutional

code.

50. The data transmission system as claimed in any one of claims 26-49, wherein said error-detecting code is a CRC code.

51. A transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other; and

means for transmitting the generated frame data.

52. A transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged after the

corresponding transmitted data and bit arrangements of the transmitted data and of the error-detecting code are set in the same order; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, said means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code.

53. A transmitter that puts variable length transmitted data into frames of a fixed time length and transmits these frames, comprising:

means for calculating an error-detecting code of the transmitted data, frame by frame;

means for generating frame data containing the transmitted data and the calculated error-detecting code such that the error-detecting code is arranged ahead of the corresponding transmitted data; and

means for transmitting the generated frame data,

wherein if the number of bits of the transmitted data is zero, said means for calculating the error-detecting code considers a previously-specified bit pattern to be the error-detecting code.

54. A receiver for receiving frame data containing variable length transmitted data, and an error-detecting code calculated, frame by frame, for said transmitted data

in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, and bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result.

55. A receiver for receiving frame data containing variable length transmitted data and an error-detecting code calculated, frame by frame, for said transmitted data in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, and if the number of bits of the transmitted data is zero,

a previously-specified bit pattern is considered to be the error-detecting code, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein said means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said means for determining determines that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

56. A receiver for receiving frame data containing variable length transmitted data and an error-detecting code calculated, frame by frame, for said transmit data in each frame of a fixed time length such that the error-detecting code is arranged ahead of the corresponding transmitted data, and if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, comprising:

means for receiving the frame data;

means for assuming the transmitted data and the error-detecting code by assuming a final bit position of the frame data, frame by frame, for the received frame data, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein said means for calculating the error-detecting code also assumes a position where the number of bits of the transmitted data becomes zero as the final bit position of the frame data, and

if the error-detecting code when the position where

the number of bits of the transmitted data becomes zero is assumed as the final bit position of the frame data agrees with said previously-specified bit pattern, said means for deciding decides that the position where the number of bits of the transmitted data becomes zero is the final bit position of the frame data.

57. A receiver for receiving frame data containing variable length transmitted data, an error-detecting code calculated, frame by frame, for said transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, if the number of bits of the transmitted data is zero, the previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at the assumed final

bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

58. A receiver for receiving frame data containing variable length transmitted data, an error-detecting code

calculated, frame by frame, for said transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged ahead of the corresponding transmitted data, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculating a likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed

transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within a predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein the predetermined range regarding the likelihood difference at said means for deciding depends on the assumed final bit position of the frame data.

59. A receiver for receiving frame data containing variable length transmitted data, transmission rate information indicating the number of bits of the transmitted data calculated, frame by frame, for said transmitted data, an error-detecting code calculated, frame by frame, for said transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged after the corresponding transmitted data, bit arrangements of the transmitted data and of the error-detecting code are set in the same order, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone

error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and at the same time the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein both said means for conducting the error-correcting decoding and said means for calculating the

error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said means for deciding does not decide that the assumed position is the final bit position of the frame data,

said means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code

agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at said means for determining depends on the assumed final bit position of the frame data.

60. A receiver for receiving frame data containing variable length transmitted data, transmission rate information indicating the number of bits of the transmitted data calculated, frame by frame, for said transmitted data, an error-detecting code calculated, frame by frame, for said transmitted data, and a tail bit in each frame of a fixed time length such that the error-detecting code is arranged ahead of the corresponding transmitted data, if the number of bits of the transmitted data is zero, a previously-specified bit pattern is considered to be the error-detecting code, and the frame data has undergone error-correcting coding with a convolutional code and interleaving, comprising:

means for receiving the frame data;

means for conducting deinterleaving of the received frame data;

means for assuming a final bit position of the frame data, frame by frame, for the frame data that has undergone the deinterleaving, and conducting error-correcting decoding thereof by the maximum likelihood decoding method

up to said assumed final bit position;

means for assuming the transmitted data and the error-detecting code by assuming the final bit position of the frame data, frame by frame, for the frame data that has undergone the error-correcting decoding, and calculating the error-detecting code of the assumed transmitted data;

means for deciding that among the assumed final bit positions of the frame data, a position where an obtained likelihood difference is within a predetermined range and at the same time the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data; and

means for acquiring the transmitted data on the basis of said decision result,

wherein both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code first assume the final bit position of the frame data on the basis of the transmission rate information in the received frame data, and if said means for deciding does not decide that the assumed position is the final bit position of the frame data,

said means for conducting the error-correcting decoding assumes the final bit position of the frame data, frame by frame, for the received frame data, conducts the error-correcting decoding thereof by the maximum

likelihood decoding method up to said assumed final bit position, and at said assumed final bit position, calculates the likelihood difference between the maximum of likelihoods of a plurality of decoded data sequences that are candidates with respect to the transmitted data sequence and a likelihood of the decoded data sequence obtained by terminating the decoding with respect to the transmitted data sequence,

both said means for conducting the error-correcting decoding and said means for calculating the error-detecting code assume a position other than the final bit position of the frame data assumed on the basis of the transmission rate information in the received frame data as the final bit position of the frame data, and

said means for deciding decides that among the assumed final bit positions of the frame data, a position where the obtained likelihood difference is within the predetermined range and the assumed error-detecting code agrees with the error-detecting code calculated on the basis of the assumed transmitted data is the final bit position of the frame data, and

the predetermined range regarding the likelihood difference at said means for determining depends on the assumed final bit position of the frame data.

ABSTRACT OF THE DISCLOSURE

A data transmission method, a data transmission system, a transmitter and a receiver which can reduce the probability of detecting the rate mistakenly at the receiving side and can eliminate the need for providing buffer for temporarily storing the transmitted data at the transmitting side in variable rate data transmission are provided. At the transmitting side, an error-detecting code of the transmitted data is calculated, frame by frame, the error-detecting code is arranged after the corresponding transmitted data, and frame data is generated in such a way that bit arrangements of the transmitted data and of the error-detecting code are set in a reverse order to each other. At the receiving side, the transmitted data and the error-detecting code are assumed by assuming a final bit position of the frame data, frame by frame, for the received frame, data and the error-detecting code of the assumed transmitted data is calculated. Among the assumed final bit positions of the frame data, a position such where the assumed error-detecting code agrees with an error-detecting code calculated on the basis of the assumed transmitted data is determined to be the final bit position of the frame data.

○ TRANSMISSION BIT ORDER (D0 TO D9 SHOW TRANSMITTED DATA, C4 TO C0 SHOW CRC BITS)

CONVENTIONAL POSTPOSITION : D9,D8,D7,D6,D5,D4,D3,D2,D1,D0,C4,C3,C2,C1,C0

PREPOSITION : C4,C3,C2,C1,C0,D9,D8,D7,D6,D5,D4,D3,D2,D1,D0

FIG.1A

○ RECEIVED DATA BIT AND RECEIVED CRC BIT
(WHEN DETECTING A POSITION WHERE THE NUMBER OF BITS IS SMALLER BY ONE FROM THE CORRECT RATE POSITION)

CONVENTIONAL POSTPOSITION: DATA = D9,D8,D7,D6,D5,D4,D3,D2,D1 CRC=D0,C4,C3,C2,C1

PREPOSITION: DATA = D9,D8,D7,D6,D5,D4,D3,D2,D1 CRC=C4,C3,C2,C1,C0

FIG.1B

○TRANSMISSION BIT ORDER (D0 TO D9 SHOW TRANSMITTED DATA, C4 TO C0 SHOW CRC BITS)

CONVENTIONAL POSTPOSITION : D9,D8,D7,D6,D5,D4,D3,D2,D1,D0,C4,C3,C2,C1,C0

NEW POSTPOSITION : D9,D8,D7,D6,D5,D4,D3,D2,D1,D0,C0,C1,C2,C3,C4

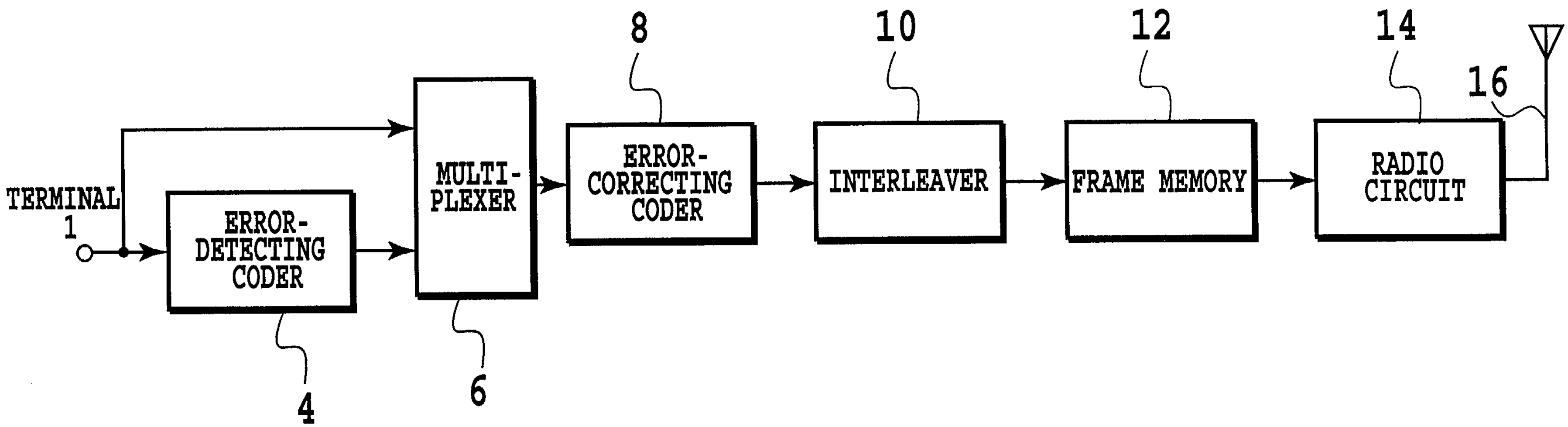
FIG.2A

○RECEIVED DATA BIT AND RECEIVED CRC BIT
(WHEN DETECTING A POSITION WHERE THE NUMBER OF BITS IS SMALLER BY ONE FROM THE CORRECT RATE POSITION)

CONVENTIONAL POSTPOSITION: DATA =D9,D8,D7,D6,D5,D4,D3,D2,D1 CRC=D0,C4,C3,C2,C1

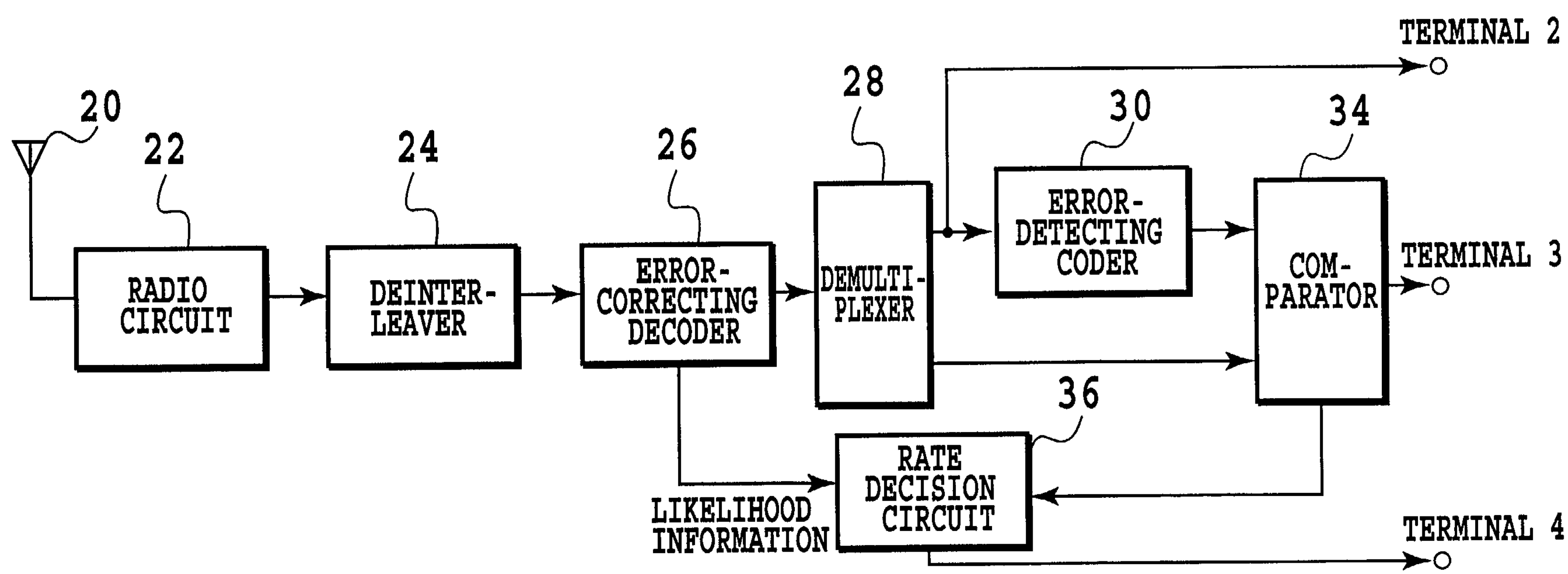
NEW POSTPOSITION: DATA =D9,D8,D7,D6,D5,D4,D3,D2,D1 CRC=D0,C0,C1,C2,C3

FIG.2B



TRANSMITTER CONFIGURATION

FIG.3A



RECEIVER CONFIGURATION

FIG.3B

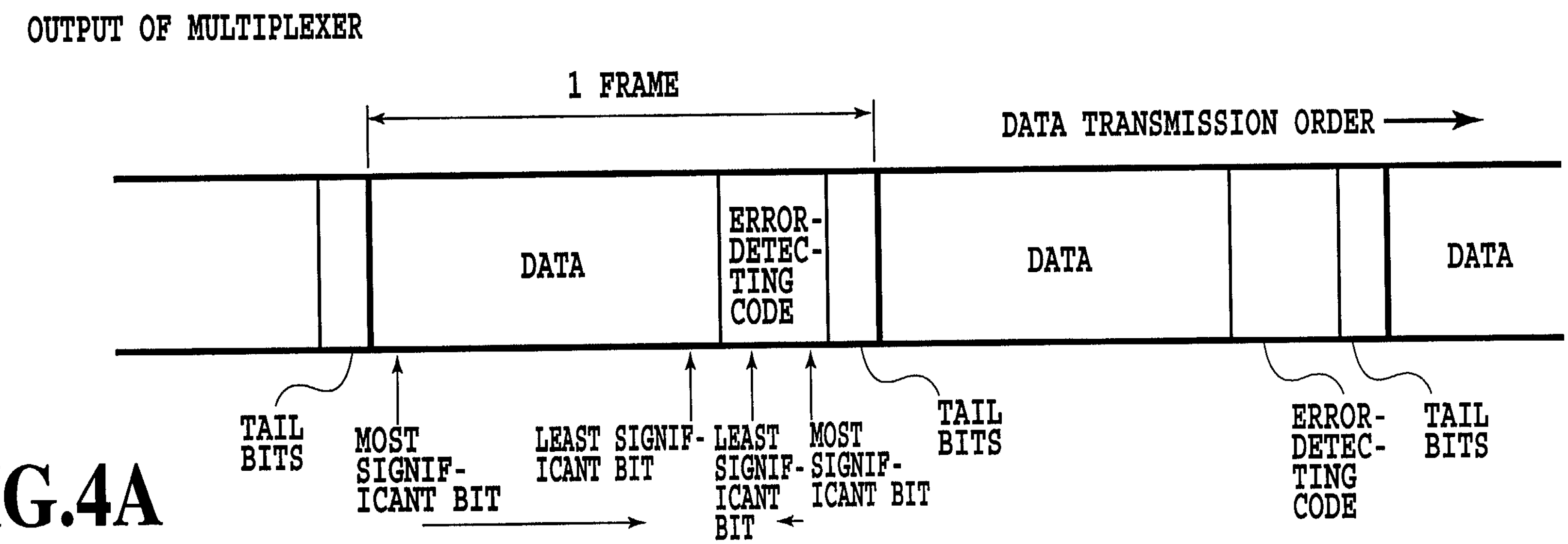

OUTPUT OF MULTIPLEXER
1 FRAME
DATA TRANSMISSION ORDER
DATA
ERROR-DETECTING CODE
DATA
DATA
TAIL BITS
MOST SIGNIFICANT BIT
LEAST SIGNIFICANT BIT
LEAST SIGNIFICANT BIT
MOST SIGNIFICANT BIT
TAIL BITS
ERROR-DETECTING CODE
TAIL BITS

FIG.4A

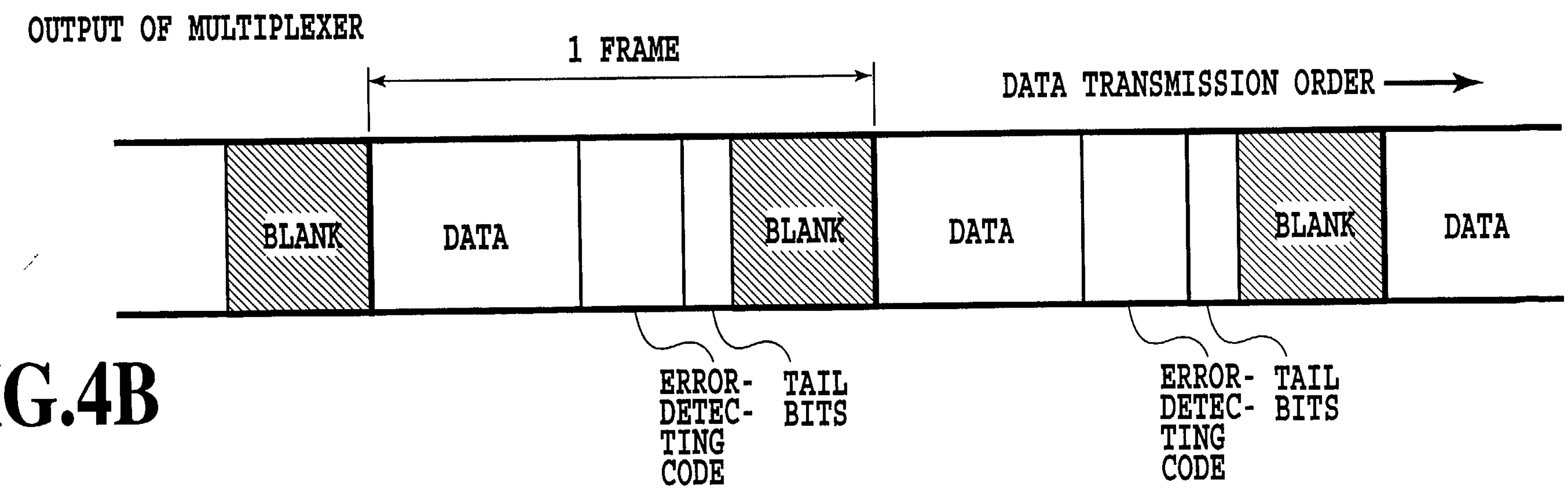

OUTPUT OF MULTIPLEXER
1 FRAME
DATA TRANSMISSION ORDER
BLANK
DATA
BLANK
DATA
BLANK
DATA
ERROR-DETECTING CODE
TAIL BITS
ERROR-DETECTING CODE
TAIL BITS

FIG.4B

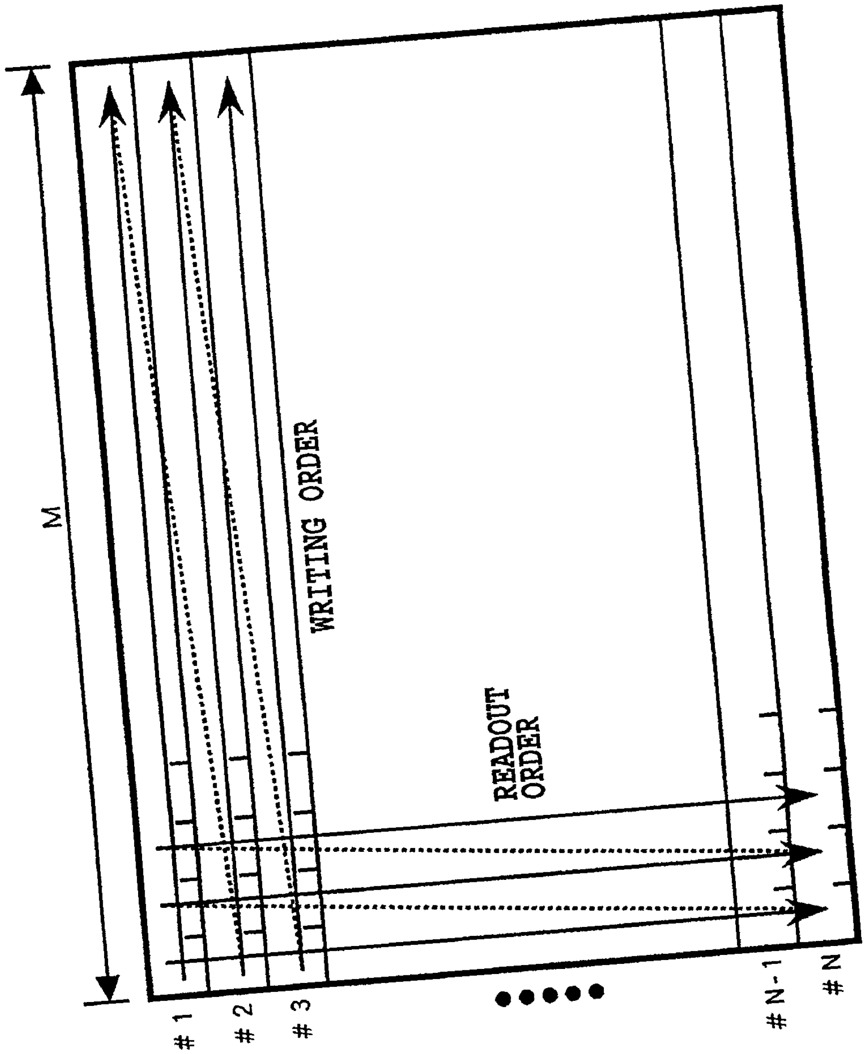


FIG.5

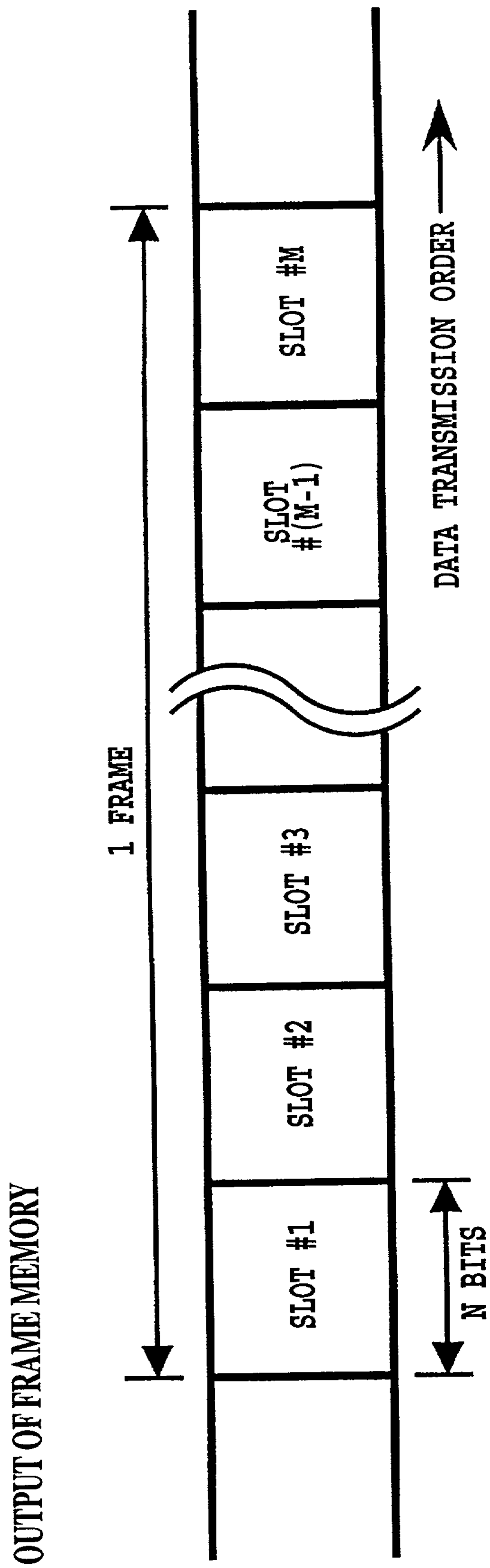

OUTPUT OF FRAME MEMORY
1 FRAME
SLOT #1
SLOT #2
SLOT #3
SLOT #(M-1)
SLOT #M
N BITS
DATA TRANSMISSION ORDER

FIG.6

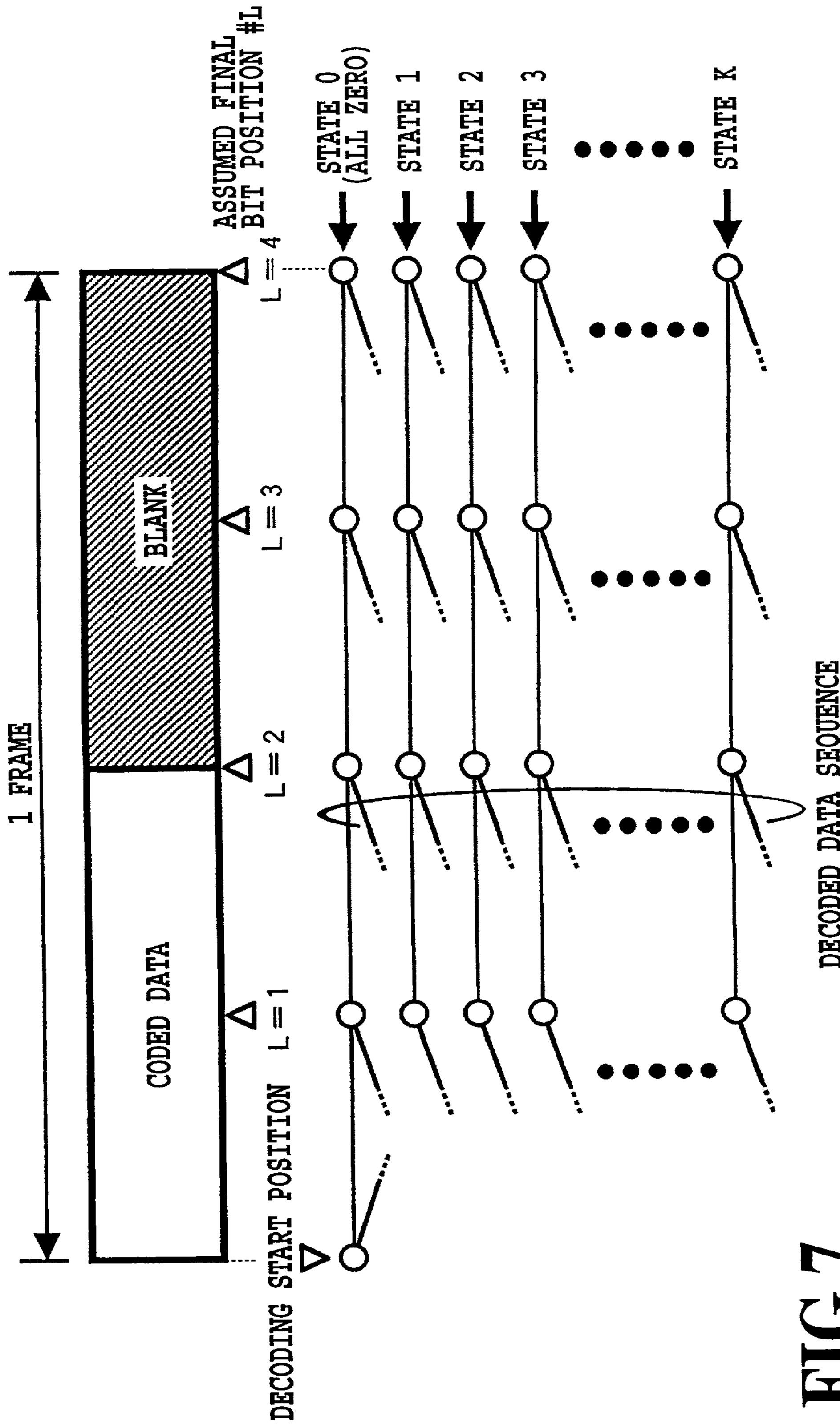
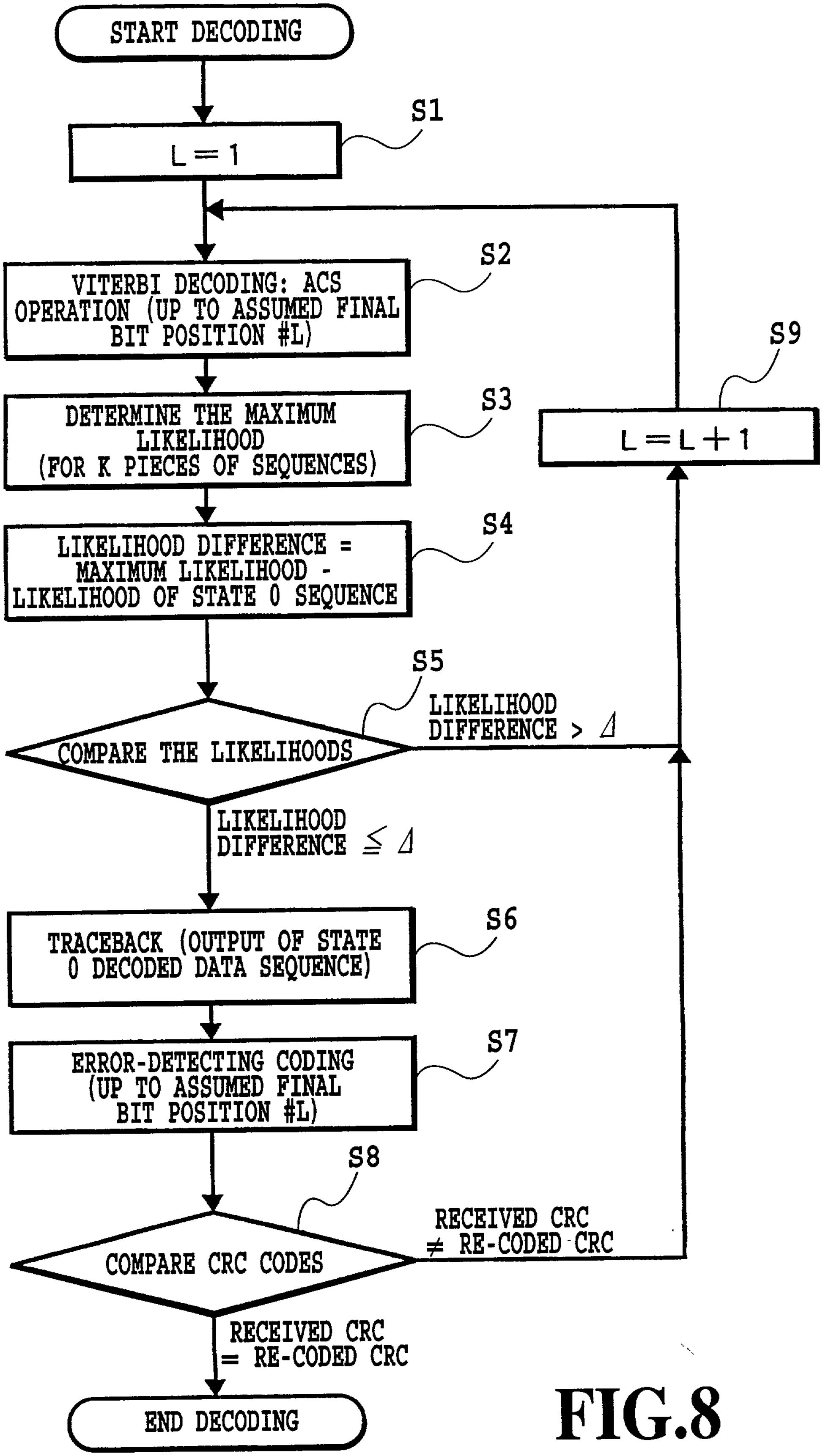

1 FRAME
CODED DATA
BLANK
DECODING START POSITION
L = 1
L = 2
L = 3
L = 4
ASSUMED FINAL BIT POSITION #L
STATE 0 (ALL ZERO)
STATE 1
STATE 2
STATE 3
STATE K
DECODED DATA SEQUENCE

FIG.7



START DECODING
S1
L=1
S2
VITERBI DECODING: ACS OPERATION (UP TO ASSUMED FINAL BIT POSITION #L)
S3
DETERMINE THE MAXIMUM LIKELIHOOD (FOR K PIECES OF SEQUENCES)
S4
LIKELIHOOD DIFFERENCE = MAXIMUM LIKELIHOOD - LIKELIHOOD OF STATE 0 SEQUENCE
S5
COMPARE THE LIKELIHOODS
LIKELIHOOD DIFFERENCE > Δ
LIKELIHOOD DIFFERENCE ≦ Δ
S6
TRACEBACK (OUTPUT OF STATE 0 DECODED DATA SEQUENCE)
S7
ERROR-DETECTING CODING (UP TO ASSUMED FINAL BIT POSITION #L)
S8
COMPARE CRC CODES
RECEIVED CRC ≠ RE-CODED CRC
RECEIVED CRC = RE-CODED CRC
END DECODING
S9
L=L+1

FIG.8

FIG.9

FIG.9A

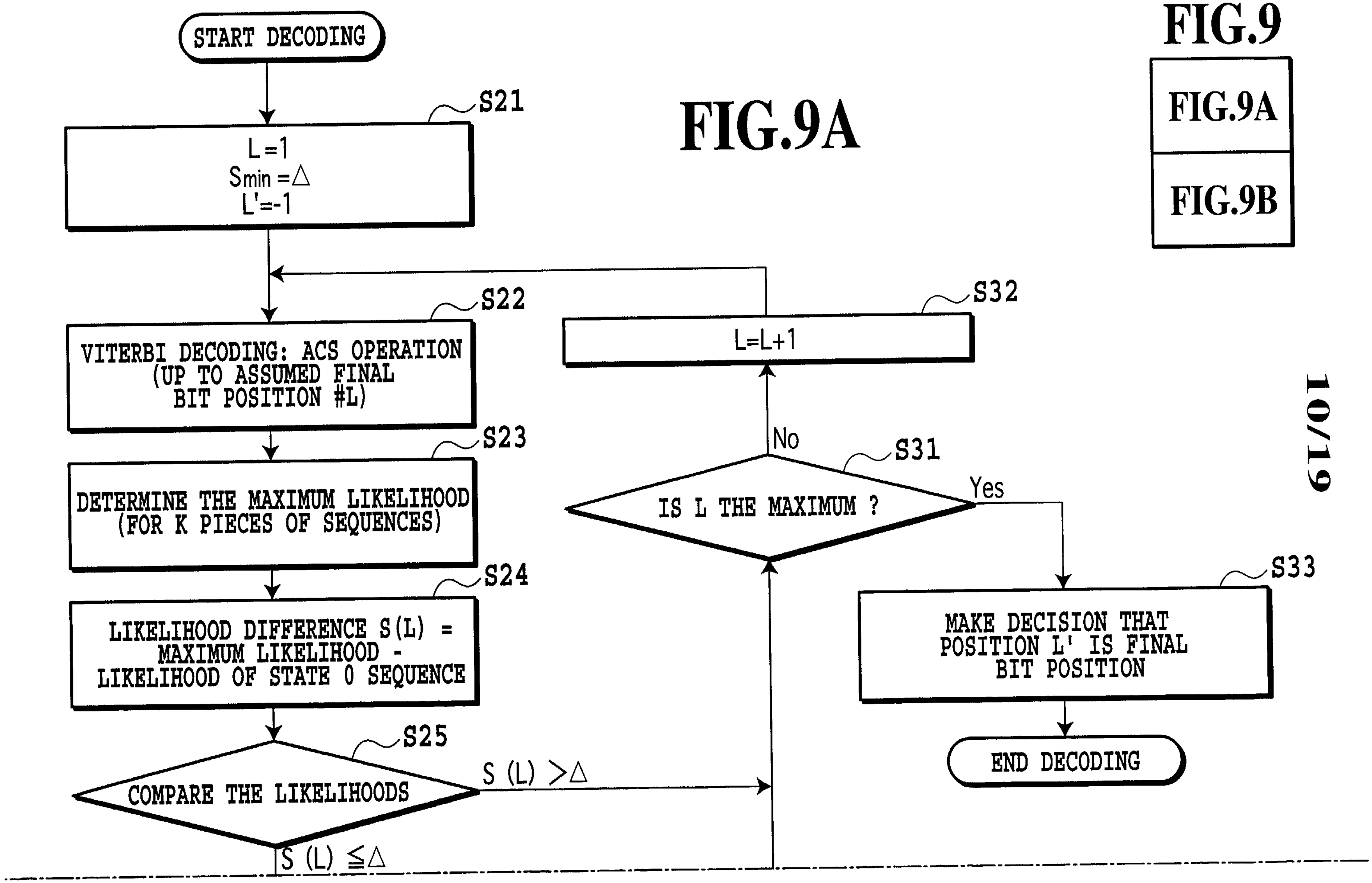
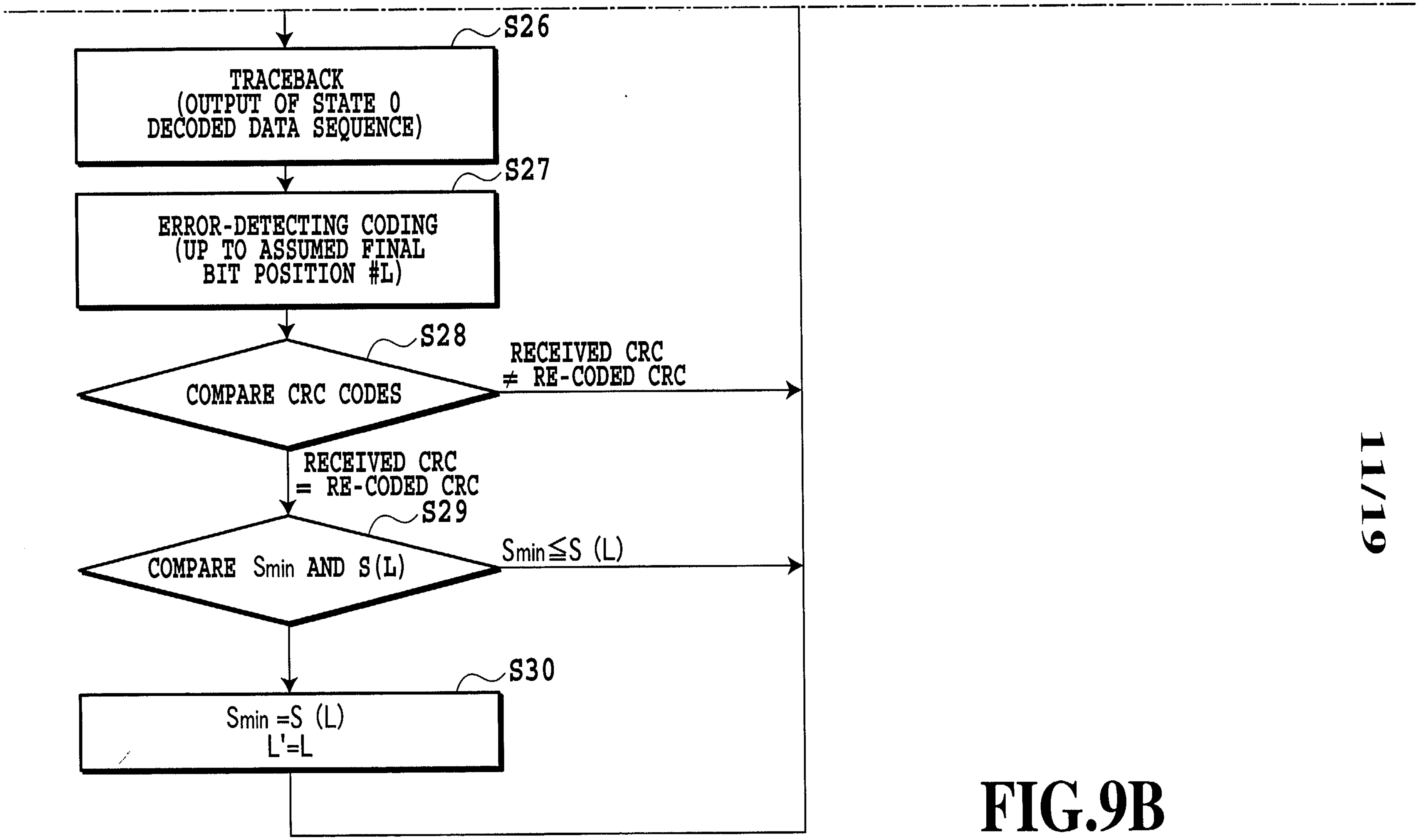
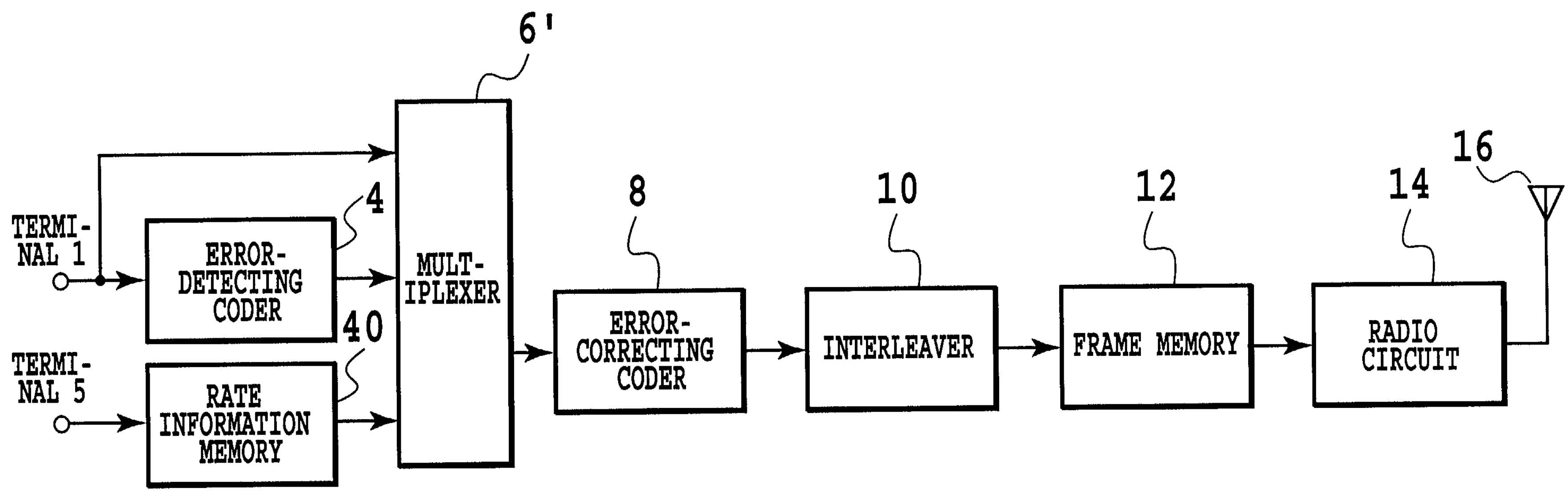


FIG.9A
FIG.9B
START DECODING
S21
L=1
Smin=△
L'=-1
S22
VITERBI DECODING: ACS OPERATION (UP TO ASSUMED FINAL BIT POSITION #L)
S23
DETERMINE THE MAXIMUM LIKELIHOOD (FOR K PIECES OF SEQUENCES)
S24
LIKELIHOOD DIFFERENCE S(L) = MAXIMUM LIKELIHOOD - LIKELIHOOD OF STATE 0 SEQUENCE
S25
COMPARE THE LIKELIHOODS
S (L) >△
S (L) ≦△
S31
IS L THE MAXIMUM ?
No
Yes
S32
L=L+1
S33
MAKE DECISION THAT POSITION L' IS FINAL BIT POSITION
END DECODING



S26
TRACEBACK
(OUTPUT OF STATE 0
DECODED DATA SEQUENCE)
S27
ERROR-DETECTING CODING
(UP TO ASSUMED FINAL
BIT POSITION #L)
S28
COMPARE CRC CODES
RECEIVED CRC
≠ RE-CODED CRC
RECEIVED CRC
= RE-CODED CRC
S29
COMPARE Smin AND S(L)
Smin≦S (L)
S30
Smin =S (L)
L'=L

FIG.9B



TRANSMITTER CONFIGURATION

FIG.10A

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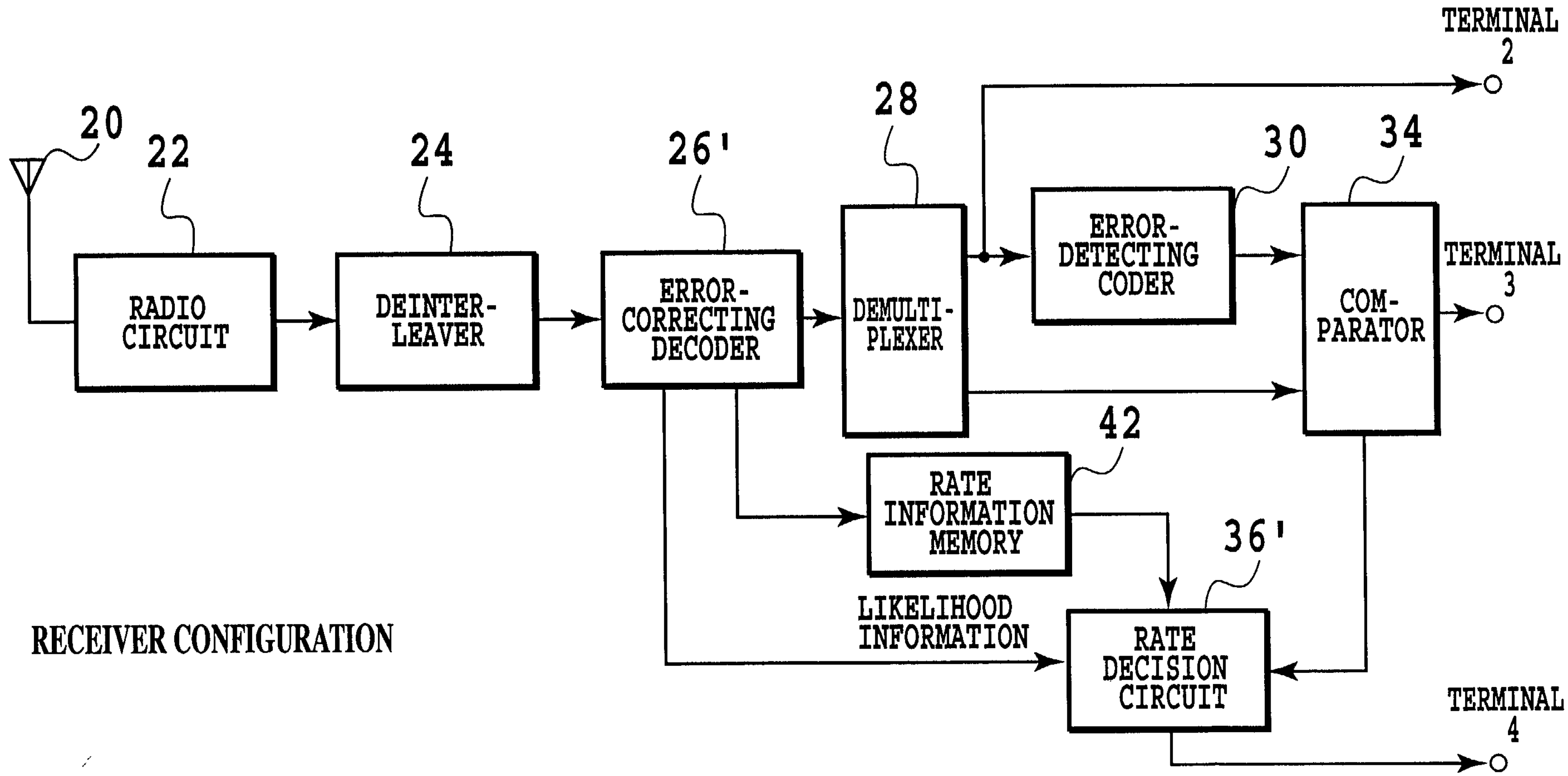

RECEIVER CONFIGURATION

FIG.10B

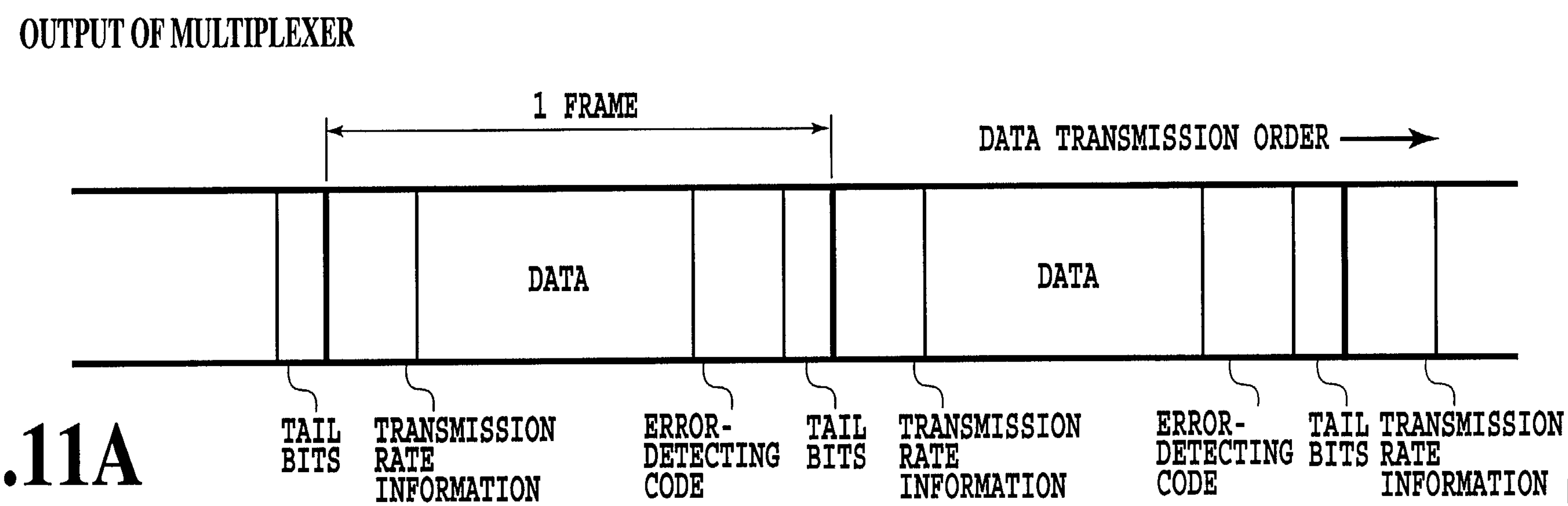

FIG.11A

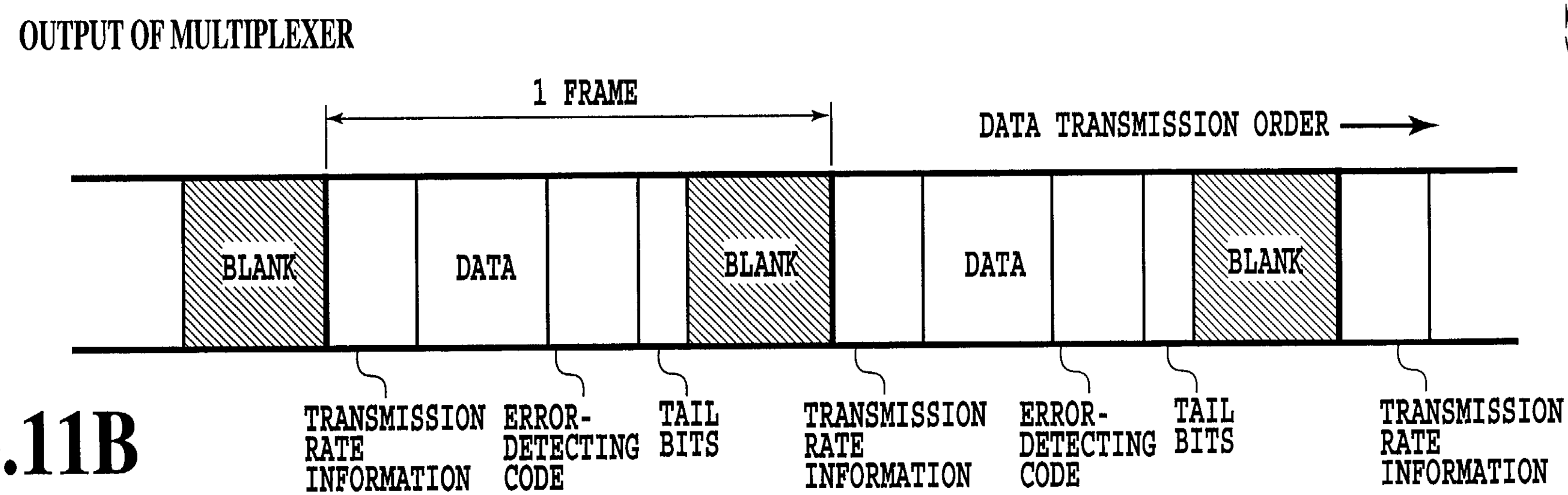

FIG.11B

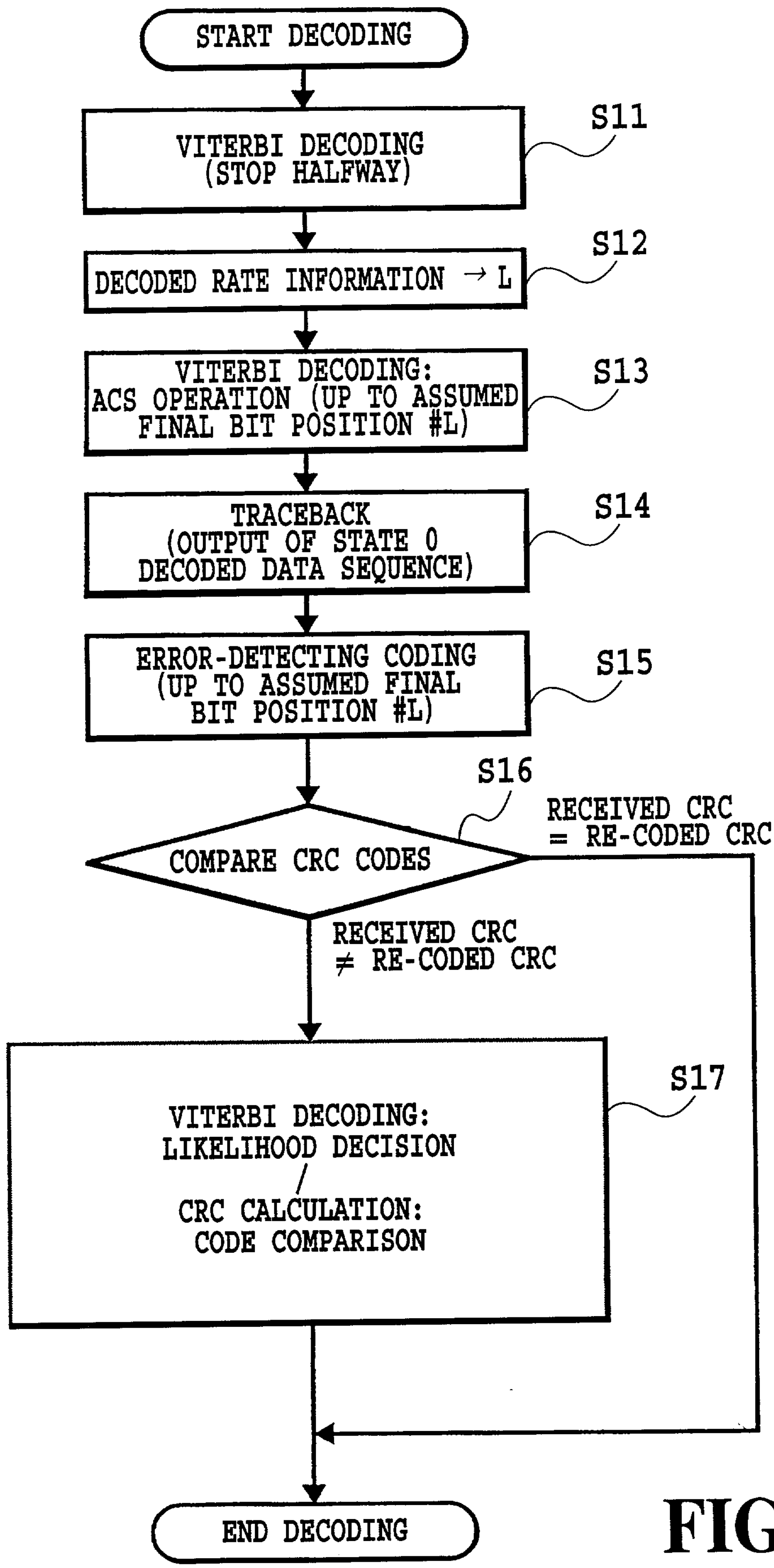
START DECODING
VITERBI DECODING (STOP HALFWAY)
S11
DECODED RATE INFORMATION → L
S12
VITERBI DECODING: ACS OPERATION (UP TO ASSUMED FINAL BIT POSITION #L)
S13
TRACEBACK (OUTPUT OF STATE 0 DECODED DATA SEQUENCE)
S14
ERROR-DETECTING CODING (UP TO ASSUMED FINAL BIT POSITION #L)
S15
S16
COMPARE CRC CODES
RECEIVED CRC = RE-CODED CRC
RECEIVED CRC ≠ RE-CODED CRC
VITERBI DECODING: LIKELIHOOD DECISION / CRC CALCULATION: CODE COMPARISON
S17
END DECODING

FIG.12

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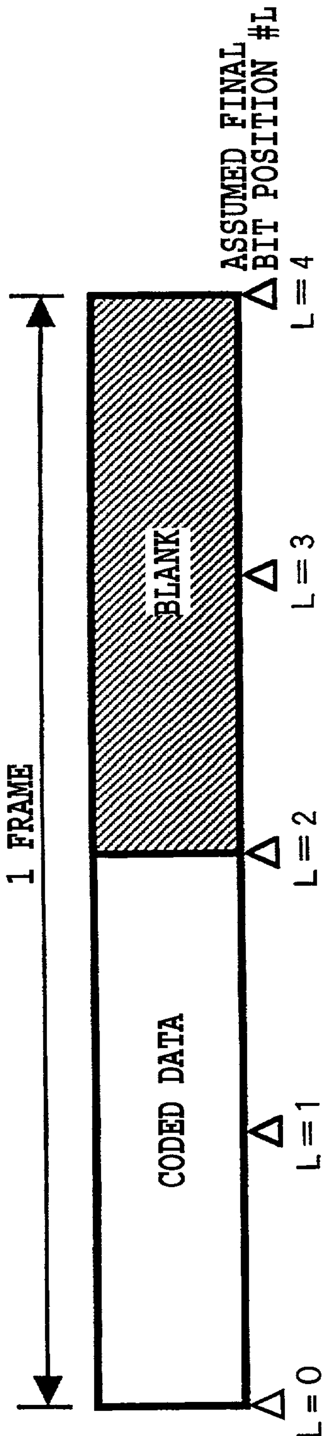

FIG.13

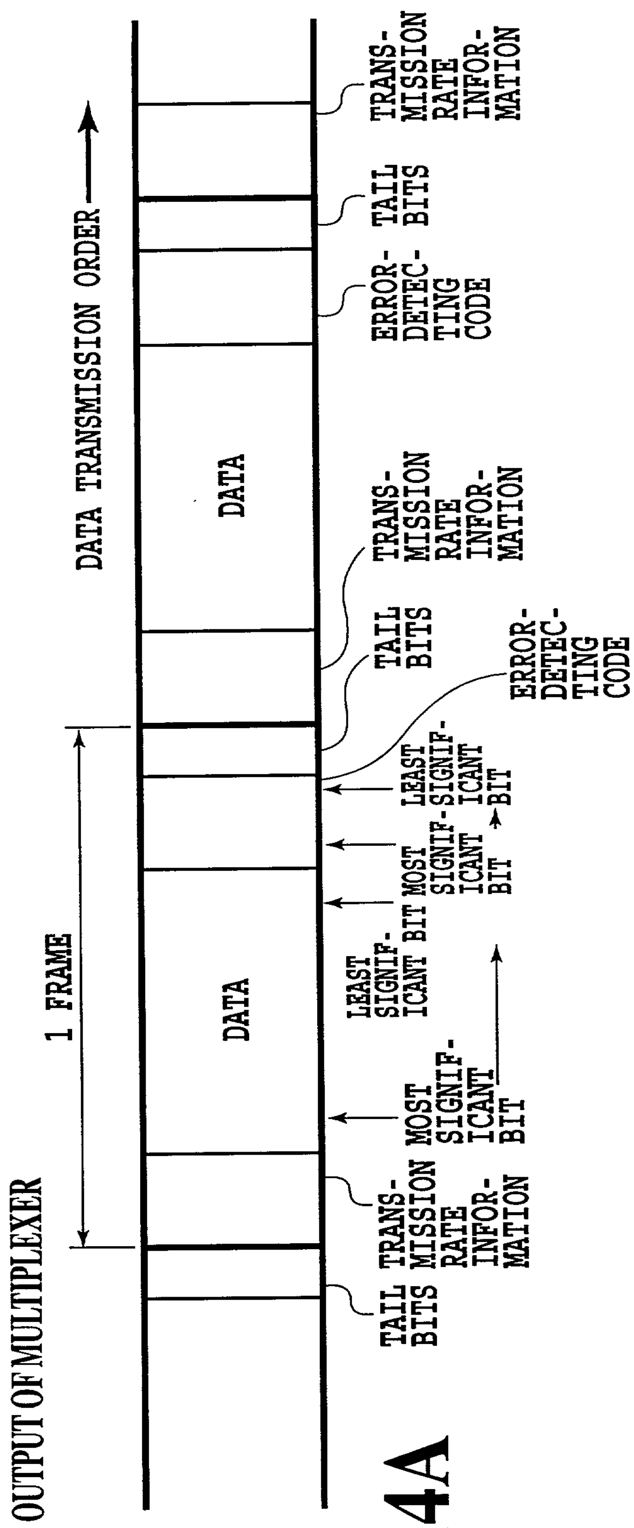

FIG.14A

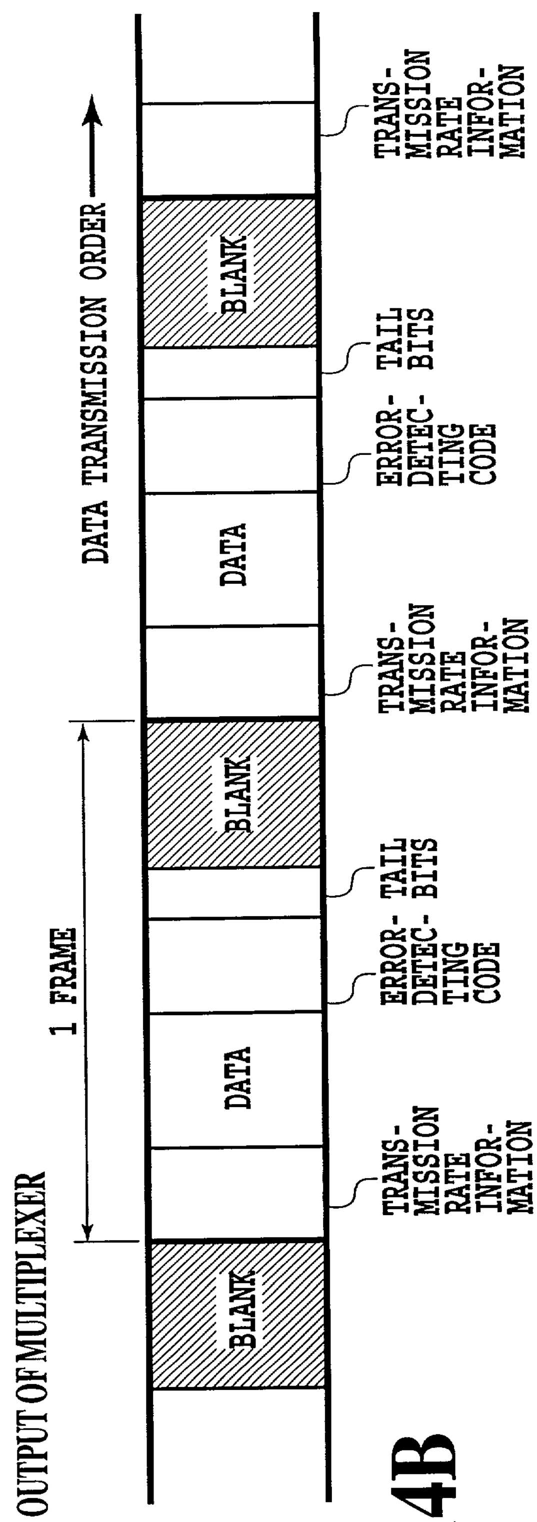

FIG.14B

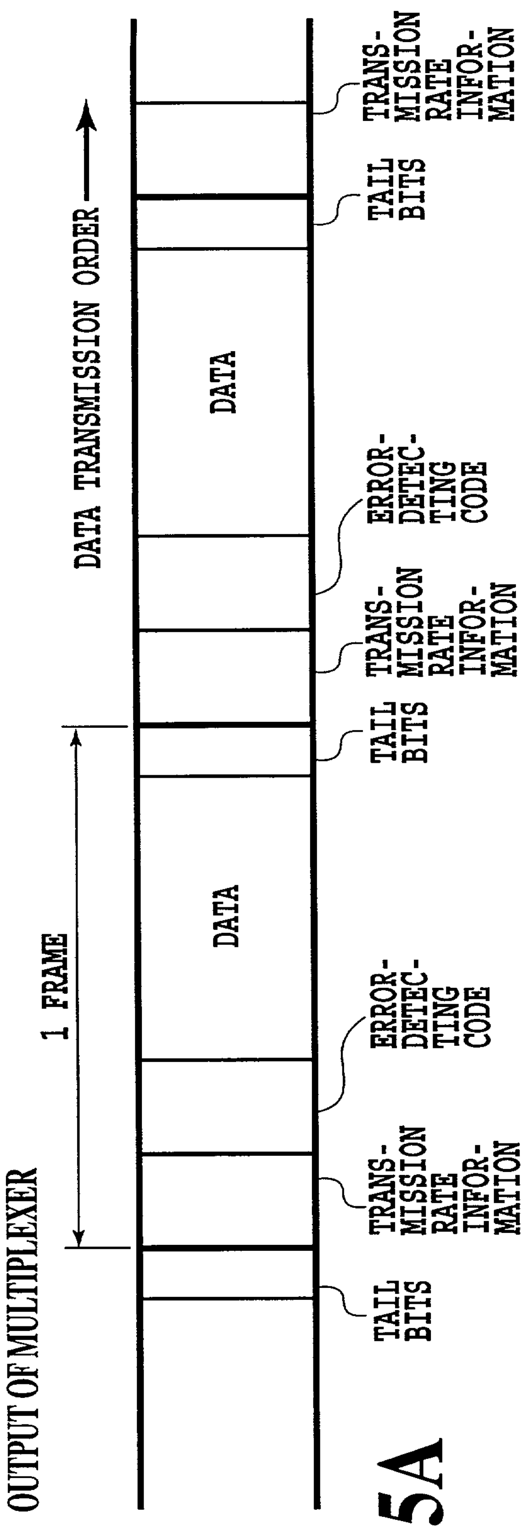

FIG.15A

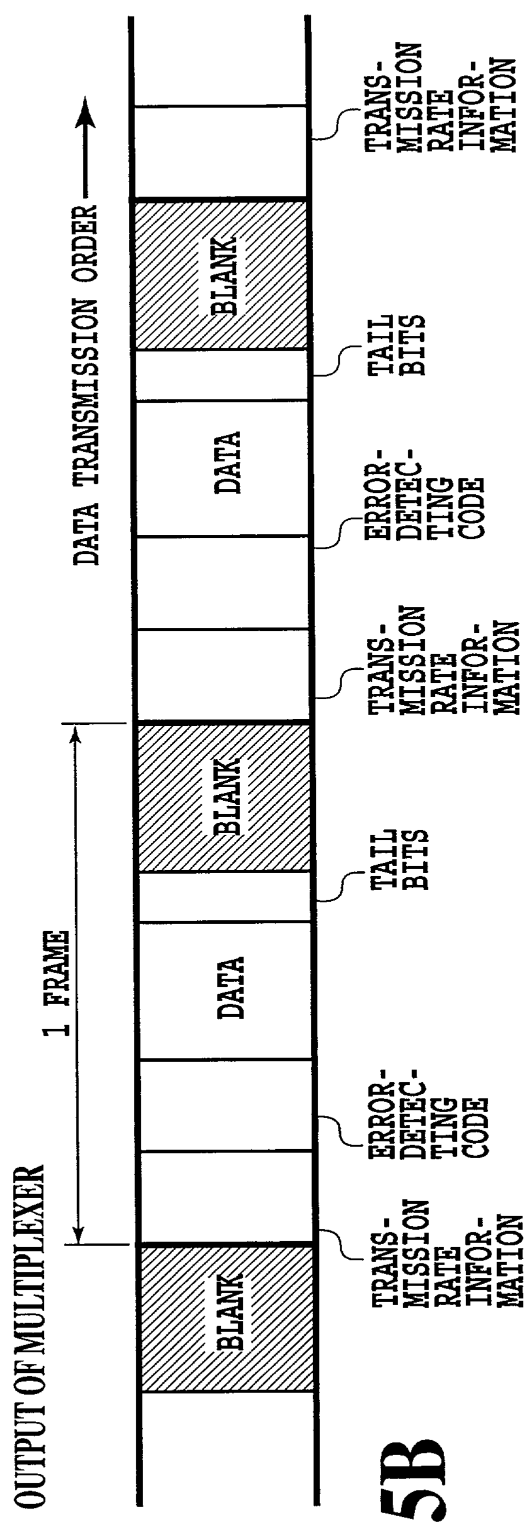

FIG.15B

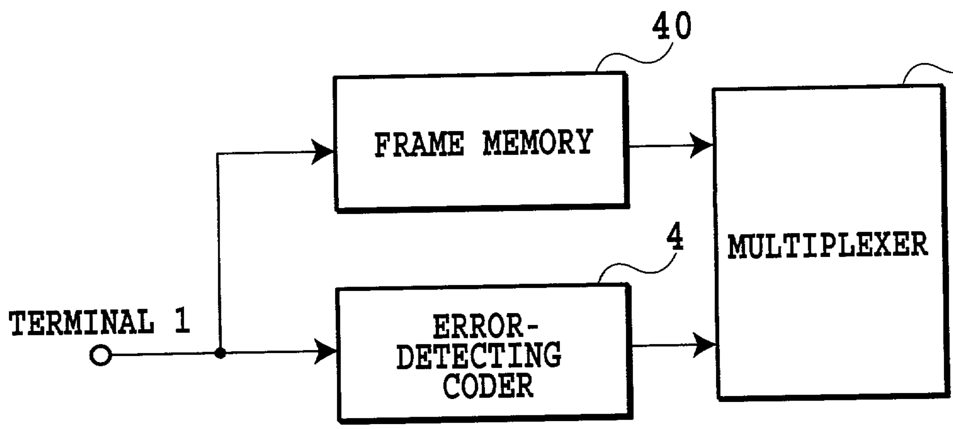

FIG.16A

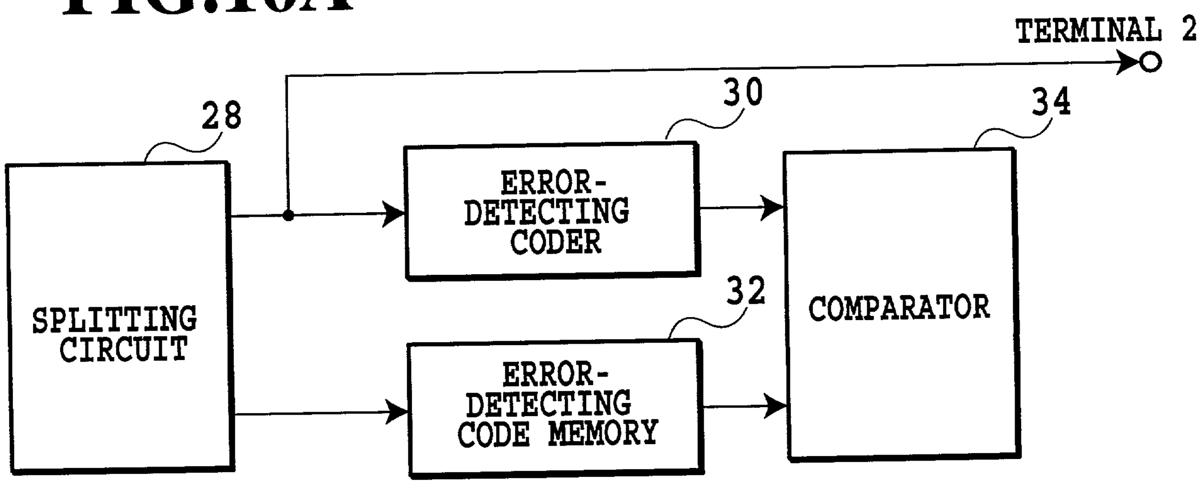

FIG.16B

Express Mail Label No. EL535 827 915US

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

(COMPLETE IF KNOWN)

Application Number	
Filing Date	21 February 2001
Group Art Unit	
Examiner	

Attorney Docket Number	3815/118
First Named Inventor	OKUMURA

This declaration is (check one):

(X) submitted with initial filing;
( ) submitted after initial filing;
( ) a supplemental declaration.

This application is of the following type:

(X) utility;
( ) design;
( ) national stage of PCT;
( ) divisional, continuation or continuation-in-part.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

DATA TRANSMISSION METHOD, DATA TRANSMISSION SYSTEM, TRANSMITTER AND RECEIVER

the specification of which: (check one)
(X) is attached hereto; or
( ) was filed on ______________________ as U.S. Application No. __________________
and is/was amended on ____________________________ (if applicable);
( ) was described and claimed in PCT International Application No. ____________________ ,
filed on ________________ and was amended under PCT Article 19 on ________________
(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby identify below, and where indicated claim foreign priority benefits under Title 35, United States Code §§ 119(a)-(d) or §§ 365(a)-(b) of any foreign application(s) for patent or

other than the United States of America, filed within 12 months (6 months for design) prior to this application, and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) on which priority is claimed (if any):

Foreign/PCT Application Number	Country	Filing Date (MM/DD/YYYY)	Priority Claimed	
11-174760	Japan	6/21/1999	(X) Yes	( ) No
			( ) Yes	( ) No
			( ) Yes	( ) No

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below (if any):

Provisional Application No.	Filing Date

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International Application designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

U.S./PCT Parent Application No.	Filing Date	Status (Patented, Pending, or Abandoned)
PCT/JP00/03650	June 5, 2000	Pending

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

As a named inventor, I hereby appoint the following attorney(s) or agent(s), of the law firm Brown Raysman Millstein Felder & Steiner LLP, 120 West Forty-Fifth Street, New York, New York, 10036, its attorneys with full power of substitution and revocation to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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(check one) Sheets containing additional joint inventors ( ) are, (X) are not attached hereto.

BRMFS1 146617.01

(12)特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2000年12月28日 (28.12.2000)

PCT

(10) 国際公開番号
WO 00/79720 A1

(51) 国際特許分類7: H04L 1/00, 29/08, H04B 14/04, H04J 13/00

(21) 国際出願番号: PCT/JP00/03650

(22) 国際出願日: 2000年6月5日 (05.06.2000)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願平11/174760 1999年6月21日 (21.06.1999) JP

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(81) 指定国 *(国内)*: AU, CA, CN, JP, KR, SG, US.

(84) 指定国 *(広域)*: ヨーロッパ特許 (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

添付公開書類:
— 国際調査報告書

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(54) Title: DATA TRANSMISSION METHOD, DATA TRANSMISSION SYSTEM, SENDING DEVICE AND RECEIVING DEVICE

(54) 発明の名称: データ伝送方法、データ伝送システム、送信装置および受信装置

a ○送信ビット順 (D0-D9は送信データ、C4-C0 はCRCビットを示す)

b 従来後置 : D9,D8,D7,D6,D5,D4,D3,D2,D1,D0,C4,C3,C2,C1,C0

c 新後置　 : D9,D8,D7,D6,D5,D4,D3,D2,D1,D0,C0,C1,C2,C3,C4

a...O SENDING BIT ORDER (D0-D9 DENOTES SENDING DATA, AND C4-C0 CRC BIT)
b...HITHETO BIHIND POSITION
c...NEW BIHIND POSITION

WO 00/79720 A1

(57) Abstract: A data transmission method, a data transmission system, a sending device and a receiving device, each of which can make it unnecessary to provide, in a variable rate data transmission, a buffer for temporarily storing a sending data in a sending side while reducing a probability of rate error detection in a receiving side. In the sending side, an error detection code of the sending data is computed for every frame, the error detection code is arranged behind the corresponding sending data, and a frame data in which a row of bits is reversed by the sending data and the error detection code is generated. In the receiving side, with respect to the received frame data, a final bit position of the frame data is assumed for every frame, the sending data and the error detection code are assumed, and the error detection code of the assumed sending data is computed. Among the final bit positions of the assumed frame data, a position where the assumed error detection code agrees with the error detection code computed on the basis of the assumed sending data is determined as the final bit position of the frame data.

[続葉有]